PUBLIC WORKS

Devoted to the interests of the engineers and technical officials of the cities, counties and states

APRIL, 1938

A. PRESCOTT FOLWELL, Editor

VOL. 69. NO. 4

W. A. HARDENBERGH, Asso. Editor

Engin.
Universal
6-23-39

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TIMEWASTERS

The Truck-Loader:

The cement and timber loaded truck was a neat little problem, not difficult, but interesting. The cement load on that last trip amounted to 6 tons and the timber to 1.2 tons. The problem of the money that Grandpa gave Johnny and the second-hand car was shamefully easy on inspection; naturally, if one good eagle-like glance is thrown onto the problem, it will be seem that Johnny had $20.79 to start with. But the train problem was something else again. Mr. Bevan, who sent it in, says that the two trains got within 165 feet of each other. Mr. Blunk says that they approached within 176 feet of each other. We have our own idea on this, but would like to hear further from others.

For the Bookworm:

Here's one we snitched from Johns-Manville's Power Specialist, which runs to occasional excellent "mentalnastics"—to use their term. To number all the pages in a book, 3001 digits are used. How many pages are there in the book.

The Stair-Stander:

And a right good one from John Bevan, who has recently resumed his contributions—his welcome contributions—to this column. Over the door of a house there is a window 2 ft. high, with the bottom edge of the glass 7 ft. above the ground level. The door faces a river 34 ft. broad, whose near edge is 20 feet distant from a point vertically under the window. Inside the house and 8 feet from the same point, a flight of stairs rises, with treads 9 inches wide and risers 7 inches high. A man is standing on the stairs trying to see through the window as great a width of the river as he can. On which stair should he stand if his eye is 5 feet above the center of the tread on which he stands.

Ikey and Mikey Promote:

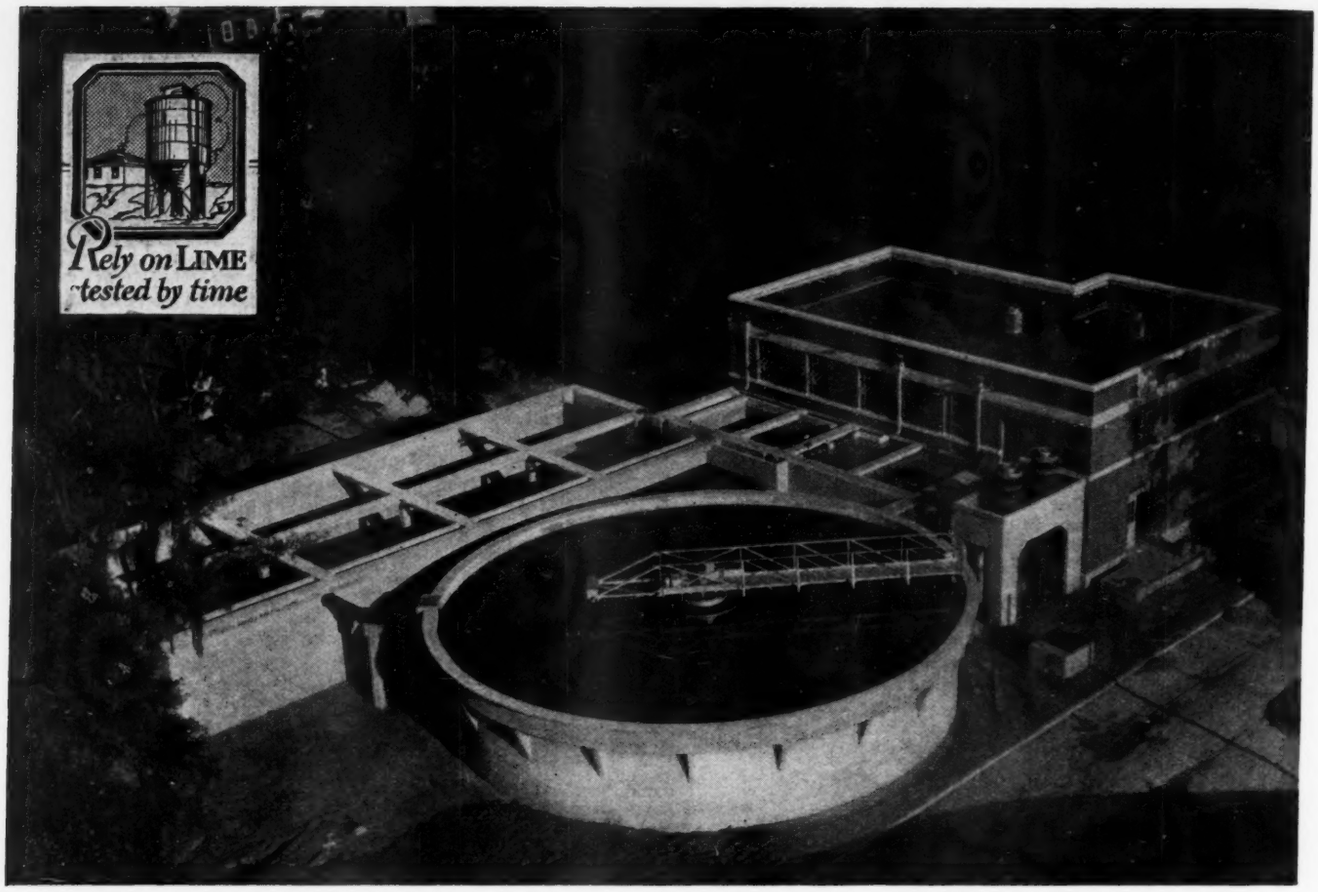
This pair are now in the prizefight promoting game. At their last fight at the My-Eyke Club, there were three prices charged for seats: $1 for general admission; $20 for ringside seats; and $50 for box seats. There were exactly 1000 seats; the "take" was exactly $10,000. Yes, the boys are in the big money now—but how many seats of each kind were there?

W. A. H.

SUBSCRIPTION RATES: United States and Possessions, Canada, Mexico a nd Cuba, $3.00. All other countries, $4.00. Single Copies, 35 cents each.

FOUNDED IN 1896

Published monthly by the PUBLIC WORKS JOURNAL CORPORATION, 310 E. 45th St., New York, N. Y. J. T. MORRIS, *President;* W. A. HARDENBERGH, Vice-Pres.; CROXTON MORRIS, *Treasurer. Advertising Manager,* ARTHUR K. AKERS, 310 East 45th St., N. Y. *Advertising representatives,* FRED R. JONES, 228 No. La Salle St., Chicago, Ill.; ALONZO HAWLEY, 1635 E. 25th St., Cleveland, Ohio.



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For descriptions of helpful booklets and catalogs, see pages 79-81.

APRIL, 1938
Vol. 69, No. 4

PUBLIC WORKS
City, County and State Engineering and Construction

The Operation of Water Treatment Plants

See pages 20 to 50 of this issue

WATER WORKS operation cannot be learned from books alone; nor solely from experience. Practical knowledge of how a treatment plant works, reinforced and broadened by reading and study of what others have done and are doing, results in a capable operator—an asset to his community. The water works field is a peculiar one, in that it lays upon its workers a heavy responsibility for safe and palatable water supplies, although it reimburses them inadequately and, in many instances, permits them to be at the mercy of politics.

State Boards of Health have been among the leaders in offering training facilities to operators and superintendents, and the past few years have seen advancement in knowledge of how to operate water treatment plants. To provide a basic and complete text, covering the fundamentals of this subject, PUBLIC WORKS has prepared the material appearing in this issue. It is not thought that all of it will be of real value to the leaders in this field; it is not intended to be, because one text cannot fill the needs of everyone. Instead, it is intended to provide a broad foundation on which the operator may build further, and to help the state boards of health in their work of education. It is hoped that it will be of service in aiding the advancement of individuals, and so of the profession, and that it will result in providing safer water and in furthering the cause of public health.

For their very valuable help and advice in the preparation of this text, the publishers of PUBLIC WORKS wish to thank the men whose names are listed below. A mimeographed preview copy of 94 typed pages was sent to each of them. From the hundreds of resulting suggestions and corrections made by them, the text published in this issue finally resulted.

Collaborators in the preparation of this text

V. N. EHLERS, State Sanitary Engineer of Texas.
RICHARD MESSER, State Sanitary Engineer of Virginia.
W. W. TOWNE, State Sanitary Engineer of South Dakota.
W. H. WEIR, Ass't State Sanitary Engineer of Georgia.
F. C. DUGAN, State Sanitary Engineer of Kentucky.
F. H. WARING, State Sanitary Engineer of Ohio.
H. W. STREETER, U. S. Public Health Service.
CHARLES P. HOOVER, Consulting Engineer, Columbus, O.
GEORGE L. HALL, State Sanitary Engineer of Maryland.
B. A. POOLE, State Sanitary Engineer of Indiana.
C. W. KLASSEN, State Sanitary Engineer of Illinois.
R. N. CLARK, State Department of Health, New York.
PROF. A. P. BLACK, University of Florida.
PAUL WEIR, Superintendent of Filtration, Atlanta, Georgia.
M. C. SMITH, Engineer of Water & Electricity, Richmond, Va.
PROF. H. E. MILLER, University of Michigan.
HARRY E. JORDAN, American Water Works Association, N. Y.
H. E. MOSES, Pennsylvania Department of Health.
CHARLES H. EASTWOOD, Wallace & Tiernan Co.
F. E. STUART, Activated Alum Corporation.
W. L. SAVELL, Mathieson Alkali Co.
M. F. KOBLISH, General Chemical Co.
ROBERT BROWNING, Wallace & Tiernan Co.
ELLIS PHELPS, Pardee Mfg. Co.
W. S. HELBIG, Darco Chemical Co.
A. S. BEHRMAN, International Filter Co.
M. B. TARK, Link-Belt Co.
EVERETT JONES, Simplex Valve & Meter Co.
E. A. SIGWORTH, Industrial Chemical Sales Div.
FRANK ROE, The Carborundum Co.
W. B. MARSHALL, Chain Belt Co.
J. B. BATY, Pennsylvania Salt Mfg. Co.

(Turn to page 20 for the beginning of this article)

Left, above, a ditch to carry off surface water has been lined with asphalt to prevent erosion. Right, the banks of the cut have been stabilized to prevent wind and water erosion.

Preventing Wind and Water Erosion Along Highways and Aqueducts

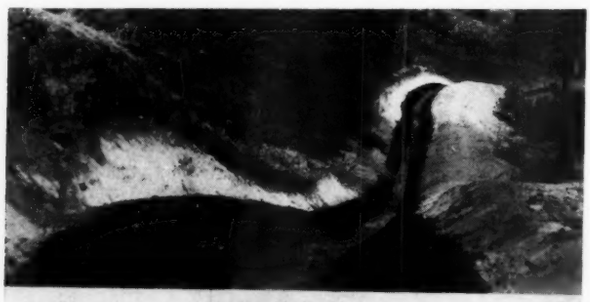
J. E. BUCHANAN

Research Engineer, The Asphalt Institute, Pacific Coast Division

THE use of asphalt for street and highway paving has become common practice and is pretty well standardized. Not so well known are its possibilities for preventing erosion by wind and water.

As a surface for shoulders, it adjusts itself to slight settlement, and, by waterproofing, prevents subgrade saturation by seepage. As a lining for gutters it has, in addition to these advantages, that of preventing erosion.

Eolian material in some regions presents a difficult control problem to maintenance organizations. Silt and sand drifts are sometimes real hazards to safe transportation besides causing a continuous drain of maintenance funds. Many solutions for control of drifting material have been tried, and among these asphalt has demonstrated its economy and effectiveness.



At top, a ditch lined with asphalt. Below, an asphalt treated mound to prevent shoulder wash.

Highway and railway banks of sand and silt are sometimes very difficult to hold in arid or semi-arid locations. If unprotected they may be eroded by wind, and subsequent deposition of the eroded material in drifts may fill ditches and cover the travel-way. Simple penetration treatments using low-viscosity slow-curing liquid asphaltic material SC-1A, have been very successful, as has a penetration treatment followed by a seal coat of soft asphalt cement. Various of these are illustrated herewith.

Another example of wind erosion prevention of considerable interest is that employed on some portions of the Colorado River Aqueduct by the Metropolitan Water District. The aqueduct location passes through a sand dune area in which the canal banks are composed of blow sand characterized by the following sieve analysis:

Passing No. 16	100%
Passing No. 30	95%
Passing No. 50	65%
Passing No. 100	25%

Samples of this material were subjected to various treatments in the district's laboratory under conditions similar to those expected at the site. These tests resulted in the selection of the following treatment

1. Application of ½ gal. per sq. yd. of 1:1 mixture of SC-1 and SC-1A.
2. Application of ¼ gal. per sq. yd. of SC-2.

The field work has done under ideal conditions, the air temperature being over 90° F., and a penetration of ½ in. was obtained.

As the canal embankment to be treated was across the canal from the service road, special construction methods were necessary. The contractor arranged an ingenious carriage spanning the canal to support the pipe line from the truck-mounted pressure distributor on the roadway to the spray lines on the opposite bank. This treatment has been pronounced satisfactory, and its cost was approximately 7½ cents per sq. yd.

Know Your Fire Hydrants

By J. W. SPRADLEY

Secy. & Sales Mgr., M. & H. Valve & Fittings Co.

Mr. Spradley

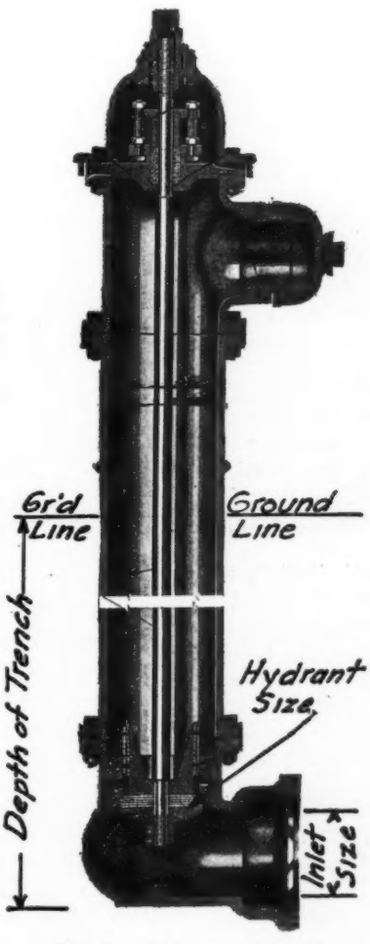
THIS article is written with the hope that it may prove helpful, not only to manufacturers, but to engineers, waterworks superintendents, purchasing agents and all who have to do with the specification, purchase and operation of fire hydrants. The object, therefore, is to explain those terms and designations that are pertinent to all types and makes of hydrants, but are often misinterpreted or omitted from a fire hydrant specification or order.

Size: The size of a fire hydrant is not the size or diameter of the pipe to which it is connected but is the size of the valve opening in the bottom of the hydrant, commonly known as the hydrant shoe, the valve opening being the inside diameter of the seat ring. The size is usually specified as 4¼, 5¼ or 6¼-inch, but sometimes they are specified as 4, 5 or 6-inch. Commercially they are the same, the difference being that the former indicates the gross area whereas the latter is the net area exclusive of the main valve rod or stem. Remember, the *size* of a fire hydrant is the gross or net diameter of the *valve opening*.

Inlet: A fire hydrant specification should state clearly the size and kind of pipe to which the hydrant is to be connected, usually 4 or 6 but sometimes 8-inch. For example, hydrants for use with bell-and-spigot pipe should be specified as *bell* or *hub* inlet, stating the size of the pipe. For the bottom end or inlet always specify *size* and *kind* of pipe with which hydrants are to be used.

Bury: More often misinterpreted than any one thing—Tom Jones says "bury" is the distance from the top of the pipe to the ground level. Bill Smith says it is the distance from the center line of the pipe to the ground level. Harry Brown says it's the distance from the bottom of the pipe to the ground level or depth of trench. Harry Brown is correct, "bury" is the same as the depth of trench, but the words "bury" or "cover" should never be used. Always give "depth of trench" which cannot be misinterpreted. It should also be remembered that fire hydrants are made in lengths to suit various trench depths and that these lengths below ground are in multiples of six inches.

Hose Connections: Usually 2½ inches inside diameter and two in number, but in rare instances the size and number may vary; so always specify the size (inside diameter) and the number of hose connections required. Most important of all is an accurate specification or description of the hose threads. The hose threads should conform to National Standard wherever possible and a majority now in use conform to this standard but in some instances it is necessary to match existing standards and in such instances the exact outside diameter of the hose threads and number of threads per inch should be given. When in doubt, send the manufacturer a male hose coupling from a discarded section of hose to use as a gauge. All hydrant manufacturers are familiar with National Standard and when your hose connections conform to this standard it is not necessary to give detail description or send samples but just say "National Standard."



What's what on a hydrant

Steamer Connection: The term "steamer" connection originated back in the days of horse drawn vehicles, steam fire engines, etc., and while the term is still commonly used, the connection is also referred to as a "pumper" connection. The size of a steamer or pumper connection is usually 4½ inches (inside diameter), with National Standard threads (5¾ inch O. D. of threads, 4 threads per inch). In some instances, however, the size as well as the threads may vary from this standard and in such instances the same instructions as set forth in preceding paragraph should be followed as to size and description of thread.

Operating Nut: It is equally important to accurately specify the size and shape of the operating nut, sometimes referred to as the wrench nut. Unless otherwise specified it is customary to make wrench nuts on the hose and steamer caps the same size as the operating nut. The "National Standard" operating nut is pentagonal (five-sided) and measures 1 7/16 inches from point to flat across the top and tapering to 1½ inches point to flat at the bottom. There are many other sizes of pentagon operating nuts in use, also square and triangular nuts of various sizes. It is therefore important to specify always the exact size and shape in your speci-

fications or orders. A pentagon nut is measured from point to flat, while a square or triangular nut is measured across the flat side.

Direction to Open: The operating wrench can turn in only one of two directions to open the valve in a fire hydrant. It is either to the left, counter-clockwise, or to the right, clockwise. When in doubt, hold your watch in your hand while opening the hydrant and if the wrench turns in the same direction as the hands on your watch, it opens to the right or clockwise, but if the wrench turns opposite to the hands on your watch, then it opens to the left or counter-clockwise. Always specify the direction to *open* and not the direction to *close*.

Color: Each manufacturer has his own standard of color combination for painting his fire hydrants, but many cities have also adopted their own standard and in such instances a complete description of the color combination should be specified, it being understood that this applies only to that portion of the fire hydrant extending above ground.

Designing Flexible Pavements

A DIGEST and discussion of published material pertinent to the design of flexible pavements has been prepared by the Division of Tests of the U. S. Bureau of Public Roads, which points out that "while our knowledge of subgrades has progressed to the point where they can be prepared more or less according to scientific principles or in such manner that they will provide reasonably uniform and constant support to road surfaces, adequate information is lacking concerning their quantitative bearing capacity, at least that type of information suitable for use in design formulas."

The report brings out that the intensity of pressure transmitted to flexible pavement subgrades may depend to a large extent upon the degree of rigidity of the surface mat as well as upon the character of the subgrade soil. In view of this it does not appear that we should attempt to apply our knowledge or conceptions of rigid footing stress distribution in soils directly to the problem of flexible pavement design.

Considerable space is devoted to a review of the methods of design of flexible pavements that have been formulated to date. While these methods have contributed to our understanding of the factors involved in the problem and have served to stimulate an interest in the problem generally, they are premised more upon existing conceptions of soil resistance and pressure distribution than upon any great amount of new or pertinent data. The discussion emphasizes the need for the development of more comprehensive test data relating directly to the problems of load-supporting capacity and pressure distribution of flexible pavements resting upon different types of subgrade soil.

Concerning the question of vehicle loads in their relation to pavement surfaces of the nonrigid type, the need for more adequate information, particularly on dynamic effect, is pointed out. It is apparent that before the required thickness of a pavement can be determined by any formula, the question as to what is the critical wheel load must be answered.

Specifically, the major parts of the general problem that demand first attention seem to be:

1. A study of the load-supporting and pressure-distributing ability of typical surfaces of the non-rigid type as influenced by—
   a. The magnitude of the load.
   b. The area of load application and the distribution of pressure intensity over the area.
   c. The time duration of the load.
   d. The physical characteristics of the surface course and of the subgrade.

It is probable that with suitable testing equipment much information of value could be developed from specially constructed test sections. However, the development of satisfactory pressure-measuring equipment for tests such as these is not a simple matter and an important preliminary task is the development of the necessary testing equipment.

2. The development of data that indicate more directly the safe load-supporting value of soils when subject to forces and displacements such as obtain under road surfaces of the nonrigid type. Factors that probably exert an important influence are—
   a. The size of the area of applied pressure.
   b. The rigidity of the surface through which the pressure is applied.
   c. The effect of restraint to vertical movement around the area of applied pressure.
   d. The physical characteristics of the subgrade material.

3. The determination of the relative effects of slowly applied and suddenly applied forces in order that the critical load for design purposes may be known.

It is apparent that the general problem is one of wide scope and great complexity. It is one of obvious importance. An early solution is not to be anticipated but great progress will undoubtedly be made toward one by the combined and coordinated efforts of the many research agencies now exploring this field.

Conditional Contract for Water Supply

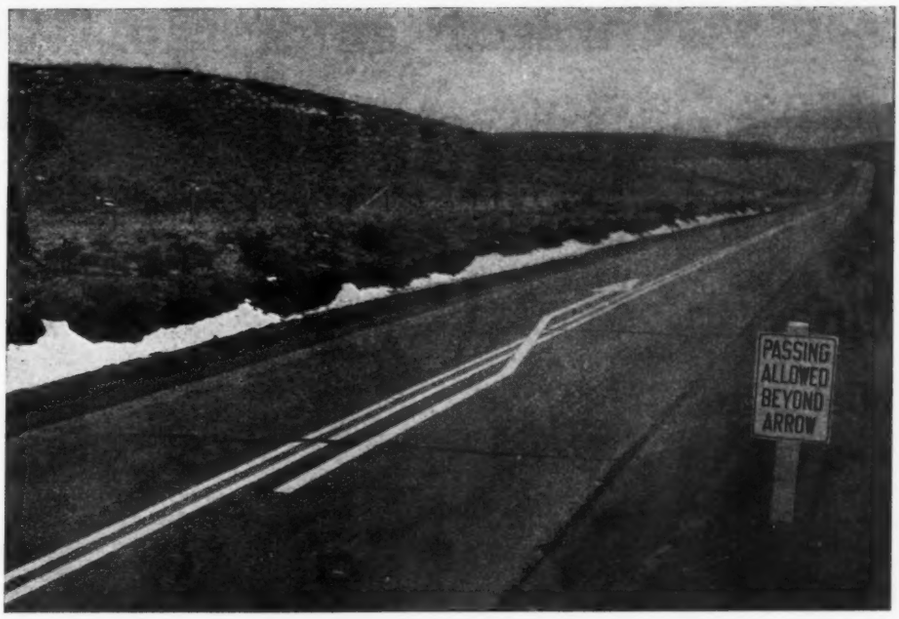
A water company's contract with a customer authorized its termination should it become impracticable to furnish water through the pipe system existing at the time of execution of the contract. The system was originally constructed by the federal government to supply a training camp, the supply being obtained by tapping the main of the Louisville Water Company. After the war the camp was abandoned and the land was parceled out to purchasers. A development company was formed to supply the owners with water. In view of the uncertainty of the life of its wooden pipe lines and other circumstances it made the above provision part of all its contracts with its subscribers. After a controversy with one of the subscribers, the company discontinued the supply. The subscriber sued, claiming damages. There was evidence that the water company could not furnish service to the plaintiff without materially reducing service to its other subscribers, and then only at a continuing loss and with the probability of being compelled to discontinue the entire service, due to the condition of the whole system of wooden pipes, and particularly those on the plaintiff's property. The Kentucky Court of Appeals therefore affirmed judgment for the water company (Bentel v. Camp Taylor Development Co., 268 Ky. 544, 105 S. W. 632).

Effect of Bursting Hydrant

A young man who was hired as a reporter encountered a lot of trouble in writing his stuff most of which found it's way into the trash basket. Finally his editor called him and said: "Look—you don't quite know what news is. For example, if a dog bites a man that's not news. But if a man bites a dog that is news." The young man thought about that and several days later the paper appeared with the following headline:

FIRE PLUG BREAKS—WETS DOG

—Midwest Purchasing Agent.



Where blind horizontals and verticals cannot be obviated through existing road courses the double white stripe has been used. It is an important safety guide. The cross-over arrow permits crossing of the double line on the down side of a hill where good visibility exists.

Nevada Safety Campaign Shows Results

BASING its procedure on effective physical structures, such as overhead and underpasses, supplemented by modern, approved educational methods, the safety campaign inaugurated and vigorously carried forward by the Nevada Department of Highways has made noteworthy progress during the past few years. The educational courses enlisted the cooperation of city and county officials and school authorities, as well as many civic organizations.

Progress resulting from the coordination of these factors is reflected in figures showing material reductions in the number of fatal and nonfatal accidents occurring annually. Persistent efforts through the various educational agencies have been made to bring before all motor car owners and drivers the many dangers which can so suddenly arise through faulty handling of the mechanical vehicle itself, or neglect of mechanical parts in the makeup of the automobile.

Coincidental with the educational phase, physical features, such as placing of signs, installing traffic lights, and displaying reflector signals at danger points along the travel ways, have all been brought into service. The driving hazards, as predetermined by instrumental surgery and engineering study, indicate to automobile drivers that caution is required, and for that reason the various signals have been spotted and mean JUST WHAT THEY SAY. With the roadside signals, the single white line on tangents, and the double line stripe on blind horizontal and vertical curves, constitute very important factors in the physical safety measures applied. Overhead and underpass structures which make for the elimination of dangerous grade crossings quite as effectively support the other physical measures adopted and used. In this connection, it is proper to state that 95 percent of the grade crossings on all main-line railroads within the state, over which primary highways cross, have been eliminated.

To make the campaign a complete success, motor car drivers must be made to recognize their responsibilities. To bring the drivers to a realization of these has been one of the prime objectives of the educational phases of the safety campaign.

Intelligent investigation and reporting of all motor car accidents is probably the most necessary measure to further highway progress; also, strict enforcement of traffic laws accomplished through the cooperation of local authorities in the various portions of the state; a system of education, beginning in the primary and secondary grades of the state schools and continuing through the higher grades, and even to adult classes, for the purpose of enlisting full cooperation of all motor car owners and the general public; and, as far as practicable, promotion of engineering methods which will improve road condition and remove specific sources of danger.

Texts and lesson outlines have been distributed for use in all public schools. Interesting, as well as educational, films prepared for the express purpose of showing danger factors in the unsafe operation of motor vehicles have been made available to educational institutions and service clubs. A standard accident reporting form has been drawn up. This material is made available to all local officials. All employees of the Department of Highways have been given instructions in principles embodied in this material. Through this method it is believed more accurate reports can be obtained concerning automobile accidents. With these comprehensive data at hand a more intelligent study of the causes of accidents is made possible, and corrective measures applied.

Immediate results show a reduction of death rate from automobile accidents in 1937 of 15% despite a travel increase of 13%.

Sludge Gas Utilization at the Wichita, Kansas, Sewage Treatment Plant*

By P. L. BROCKWAY
City Engineer, Wichita, Kan.

METER records of gas production in the Wichita digestion tanks showed a very high and constant flow of gas, seldom less than 250,000 and from that up to 300,000 feet per day. Metered use of gas almost never exceeded 70,000 and seldom exceeded 50,000 feet per day. So wide a spread between minimum production and maximum consumption made it evident that there was a possibility of eliminating the power bill of $600 to $700 per month.

An analysis of the gas showed the presence of 64% methane and 620 Btu, which is in line with available reports. Analysis made continuously for a year showed approximately 500 to 600 grains of H_2S per 100 cubic feet, seldom outside these limits. The concentration is highest immediately after a fresh charge of sludge is pumped into a tank; Fig. 4 shows H_2S concentration gradually declining with decreased gas production but persisting at 160 grains per 100 cubic feet as long as gas was produced. No engine manufacturer was or is willing to guarantee an engine to operate without very serious depreciation with so much corrosive gas.

Investigation of standard H_2S scrubbers indicated an operating expense greater than the saving in the power bill; and we doubted the necessity of scrubbing the gas, judging from our experience with the hot water heating boilers in this plant. The house heating boiler and hot water heater circulated water at about 180°. The tank heater was a standard thermostat-controlled automatic heater, with no change for sewer gas except adjustment of the air mixer, which had to be operated with a maximum circulating water temperature of 125° to 135° to avoid caking sludge on the pipes within the digester. These heaters produced so much sulphur dioxide as to make the atmosphere fairly unendurable, the stack not carrying it off; also sulphur trioxide collected on the boiler housing, destroying it and running down on the floor where it hardened. The whole thing was a mess until some three-way thermostat-controlled valves were installed with a bypass system which shunts part of the water around the boiler, permitting internal temperatures to be anything under the boiling point. Actually the operating temperature now is kept about 180°, and SO_2 and SO_3 troubles are eliminated.

Reasoning from this, it seemed a fair conclusion that the operating temperature in the engine would delay corrosion at least until it paid for itself in power saving, with a more than reasonable expectation that the life of the exposed metals would be much longer; and a 6-cylinder, 6 x 7-inch Climax engine was installed, replacing a 75 hp. motor on a raw sewage pump designed for a capacity of 10 mgd at an operating head of 28 feet at 360 rpm, with an anticipated fuel consumption of about 20 cu. ft. per hp. hr. This installation has operated successfully from the beginning.

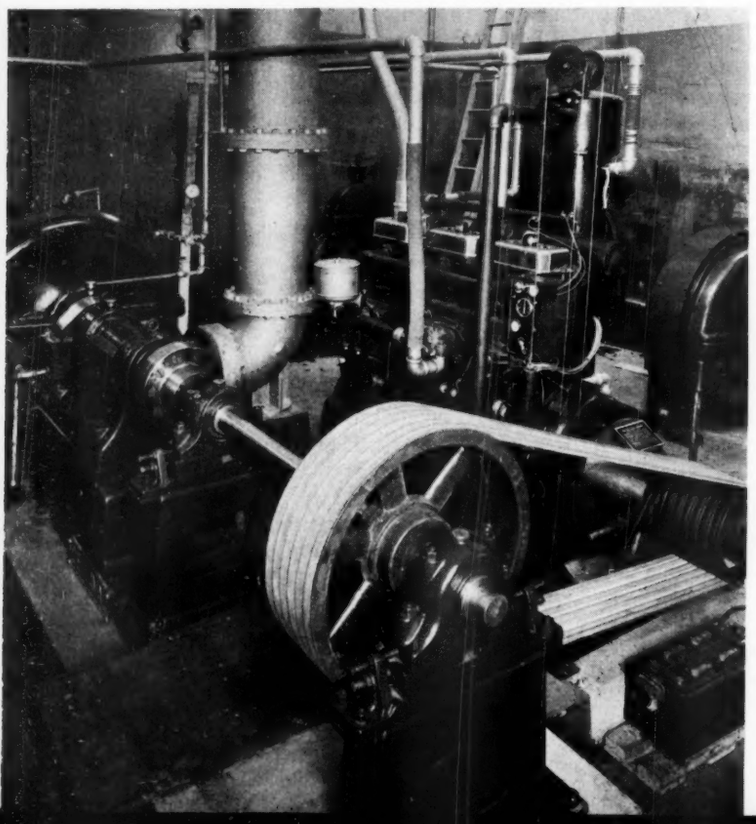
The engine runs opposite to the pump; floor space did not permit direct connection to the pump shaft, so the engine is turned around beside the pump and a V belt connection made, with a speed ratio of 750 for the engine to 360 on the pump. To permit continuous operation during low-flow periods speed is controlled by a float in the wet well. Daily variation is from about 4 to 13 mgd, with engine speed varying from 600 to 760 rpm. This operation has a very decided advantage of providing continuous rather than intermittent flow through the plant.

After running almost continuously during the first six months for a total of slightly more than 4,000 hours and an average of 165 hours per week, the engine is operating perfectly smoothly. At the end of the 1,700 hours, when it was shut down to replace some worn parts on the pump, examination revealed no indication of corrosion, scoring or any damage whatever. The valves were slightly warped and were refaced. One rocker arm adjusting screw on the valve mechanism was replaced at about 3,000 hours. Spark plugs have been changed once.

Cooling is by a tubular heat exchanger. External water is pumped out to a spray cooling tower. The temperature indicator on the engine showed a temperature in the neighborhood of 200° most of the summer and fall, but we doubted the evidence of the instrument and calibration with a standard thermometer showed it to be unreliable above 170°. A replacement from the manufacturer was found to be equally unreliable. Mercury thermometers were installed in the intake and outlet pipes of both the interior and exterior circulating systems and showed about 80° in and 100° out on the outside circulation and 166° in and 200° out on the engine circulation. Water in the external system con-

*The last of three articles; the others appeared in the February and March issues.

Gas engine operating raw sewage pump at Wichita.



tains about 250 ppm each of calcium and sulphate hardness. The heat exchanger was treated to a commercial hydrochloric aid bath and the temperatures then became 120° into and 160° out of the engine and 70° to 78° into and 90° to 95° out of the cooling circuit. The manufacturer recommends 170° from the engine. Low temperatures reduce lime deposit in the heat exchanger, while high temperatures may reduce H_2S corrosion in the engine. Of the two, we would prefer the lime deposit.

Figure 6 shows the pertinent items of power operation. During this period the engine was shut down about one-half hour per day for oil adjustment and servicing; except for that, it has pumped the entire flow with two short exceptions indicated by the power graph. Electric power is used only to operate auxiliary service which runs on a very definite uniform schedule and should be quite uniform.

Gas consumption and sewage volumes are measured by meters. Electric consumption is metered on the power company's line ahead of the transformer at the plant, and also on the incoming line at the switchboard, where readings are made for comparative studies.

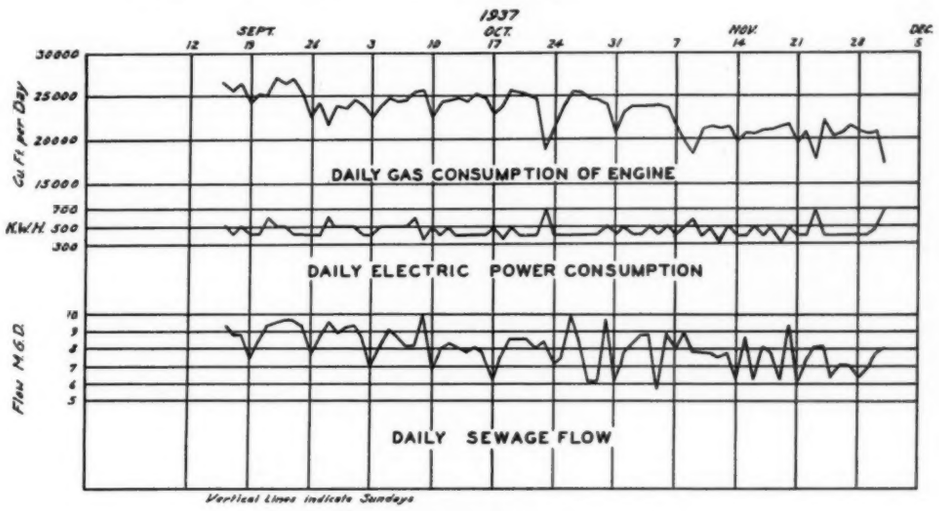


Fig. 6—Pertinent items of power operation

No attempts have been made to measure the engine output of energy but the following comparison furnishes a reasonable basis of calculation:

Electric Power Consumption and Total Sewage Flow
For 13 Weeks beginning January 22, 1937, with complete electric operation of the plant
Constant Speed—Intermittent Operation

	K. W. H.	*Million Gallons*
January 22	11,050	58.75
January 29	11,000	59.63
February 5	11,050	57.32
February 12	11,000	56.53
February 19	10,400	53.68
February 26	10,500	54.03
March 5	10,700	53.45
March 12	10,700	54.66
March 19	11,400	61.97
March 26	11,250	61.68
April 2	10,550	56.20
April 9	10,250	56.67
April 16	10,750	59.95
Total	140,600	744.52
Average	10,815	57.27

Average electric power during first period was 188.9 kwh per million gallons, and during second period was 61.8 kwh, indicating a replacement of 127.1 kwh per million gallons of electric with gas power. On this basis,

Electric Power Consumption, Hours of Gas Engine Operation, Total Sewage Flow, and Cubic Feet of Gas Consumption
In another 13 weeks' period of very similar flow of sewage
Variable Speed—Continuous Operation

	K.W.H.	*Engine Hours*	*Gas Cu. Ft.*	*Million Gallons*
September 17	3,800	168	189,000	64.97
September 24	3,600	167	167,600	62.90
October 1	3,600	165	166,620	62.77
October 8	3,600	168	168,500	59.13
October 15	3,650	166	169,630	57.48
October 22	3,200	168	173,160	55.83
October 29	3,200	164	165,090	55.12
November 5	3,450	165	163,850	57.20
November 12	3,550	161	148,790	57.12
November 19	3,350	167	146,590	52.17
November 26	3,450	163	142,980	51.12
December 3	3,850	156	141,270	51.87
December 10	3,400	165	155,830	51.77
Total	45,700	2,143	2,098,910	739.45
Average	3,515	164.85	161,455	56.88

power production by gas in the later period is 739.45 x 127.1 kwh = 93,984 kwh = 125,940 horsepower-hours. This is an average of 58.78 horsepower effective work over the 2,143 hours of operation pumping an average of 5,750 gallons per minute. Allowing 10% for loss in motor and of efficiency due to wear in pumps, the gas consumption, 20 cu. ft. per hp.-hr. or less, agrees closely with the manufacturer's estimate for this installation of 18.3 cu. ft. per hp.-hr.

Costs of maintenance and operation during the six months' period were:

Oil—252 gallons	$138.15
Manifold oil—5 gallons	2.60
Spark plugs	8.89
Grinding valves	2.40
Repairing rocker arm screws	3.45
Repairing exhaust pipe system	7.20
Change and repair to water pump	8.24
Wiping rags	14.50
Total	$185.43

Power bill is based on readings about the middle of each month. With about the same total flow, the bills have been:

	1936	*1937*	*Decrease*
July	$691.90	$321.74	$370.16
August	704.87	381.06	323.81
September	705.21	287.74*	417.47*
October	579.59	322.50	257.09
November	587.92	297.77	290.15
December	564.63	297.83	266.80
Total	$3,834.12	$1,908.64	$1,925.48
Average	639.02	318.10	320.91

*Contract rate apparently calculated on different basis September, 1937.

Deducting cost of gas engine maintenance and operation, the saving during this period is approximately $290 per month, which will pay the entire cost of installation in less than sixteen months. The two-thirds reduction in power eliminated the lower bracket of the power rates, leaving the higher fixed charge to pay.

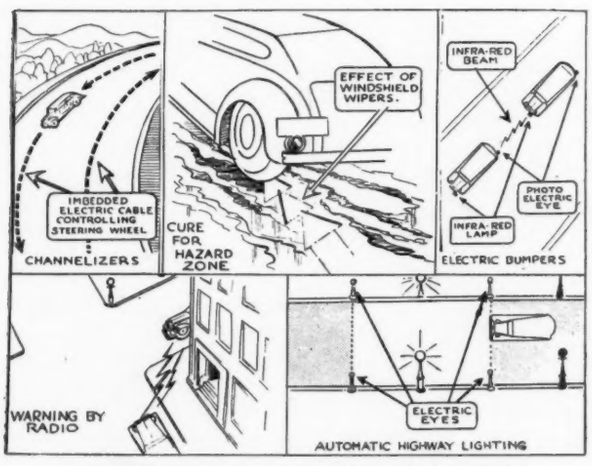
It is not anticipated that any machine can operate 165 hours per week indefinitely; but if it is demonstrated in another six months of such operation that no serious H_2S depreciation has occurred, it can safely be assumed that the city will be justified in installing additional power to have standby service, and cut off the outside energy.

It is apparent from a further examination of Figure 1 that there will still be not less than 200 hp. available for other service after complete gas engine operation of the plant, but nothing further than speculative possibilities have been considered. It seems advisable to operate for a year or two to determine definitely the effect of H_2S. Oil field operators have reported that this causes a gradual embrittlement of metal without corrosion or surface indication of depreciation.

Possibilities in Scientific Solutions of Traffic Problems

Prof. John M. Lessells, of Massachusetts Institute of Technology, an authority on friction, and Dr. Miller McClintock, director of street traffic research at Harvard University, forsee that science will succeed in developing means of (1) Guiding cars automatically into proper channels by invisible rays from cables in street. (2) Ending "hazard zone of motoring"—where skidding throws car out of control—by "giving us, in effect, a battery of windshield wipers under the car, instantaneously creating a dry surface over which the tire is always passing." (3) Using infra-red rays from car to car to slow down vehicle too rapidly approaching another. (4) Sounding radio beam warnings from one car to another when they are approaching at intersections. (5) Controlling highway lighting by electric eyes so that any given road area is illuminated only when approaching traffic requires it.

Prof. Lessells considers that one of the greatest dangers in modern motoring is "hazard zone," explaining that skidding occurs on wet pavements when a slippery film of water comes between the auto tires and the road to act as a "lubricant," and keeps the tires from gripping the road surface, and "forces beyond the driver's control take over the wheel, the brakes, the speed, and even the direction of the car he is driving. If we can instantaneously create a dry surface, over which the tire is always passing, the car's brakes will keep it under control. I anticipate that some way will soon be found to give us, in effect, a battery of windshield wipers under the car, to remove the danger of the hazard zone."



An artist's ideas of science's future aids to traffic

Dr. McClintock predicted that busy streets and highways of the future will be designed with complete separation of opposing traffic, provisions for elimination of intersections and marginal obstructions, and no cross streams of traffic. Visualizing some of the auto safety plans that science has for the future, Dr. McClintock listed:

Automatic channelizers, or electric cables in the pavement to operate radio controls and take over the steering of a car around dangerous road curves and obstructions.

Installation of infra-red lights in rear of autos to reduce the speed of approaching cars by actuating photo-electric cells which would automatically apply brakes and prevent collisions in lines of traffic.

Use of two-way radio by all cars to automatically give warning signals to a driver when an unseen car is about to cross his path.

Infra-red beams and photo-electric cells on highways which—when a car enters a certain area—would automatically turn on lighting for a given distance ahead. When the car left that area it would automatically turn off the lighting.

"We need not consider any of these ideas fantastic," Dr. McClintock concluded. "Even more seemingly impossible tasks are already being performed by similar mechanisms."

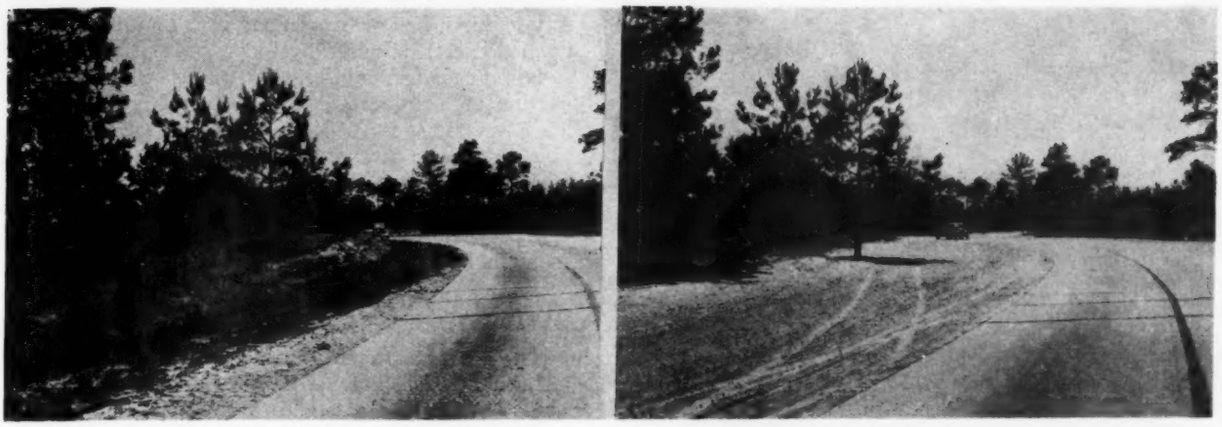
Some Maintenance Items of a Progressive Borough

Princeton, N. J., has a population of about 8,000. It is a progressive university town, with excellent sewage treatment plant and refuse incinerator. The annual report for 1937 of I. Russell Riker, the borough engineer, indicates that streets, sewers and other features of the borough are maintained in good condition and kept up to date in spite of the depression but with the assistance of WPA. Among the interesting items gleaned from the report are the following:

During January, February, March and April 515 square yards of pavement patching was done at an average cost of $1.06. During the following eight months WPA labor was used in patching 33,172 sq. yd. and the average cost was 13.6 cts. per square yard.

During the year 487.1 million gallons of sewage was pumped at an average cost of $11.76 per m.g. Administration and laboratory control cost $4,870, 5,166 chemical and bacteriological tests having been made. The total cost (including about $1500 for new equipment) was $20,201.59. Unit costs averaged 0.2 ct. per cu. ft. for removing raw sludge; 0.16 ct. for removing digested sludge; and 31.2 cts. per million gallons for final sedimentation.

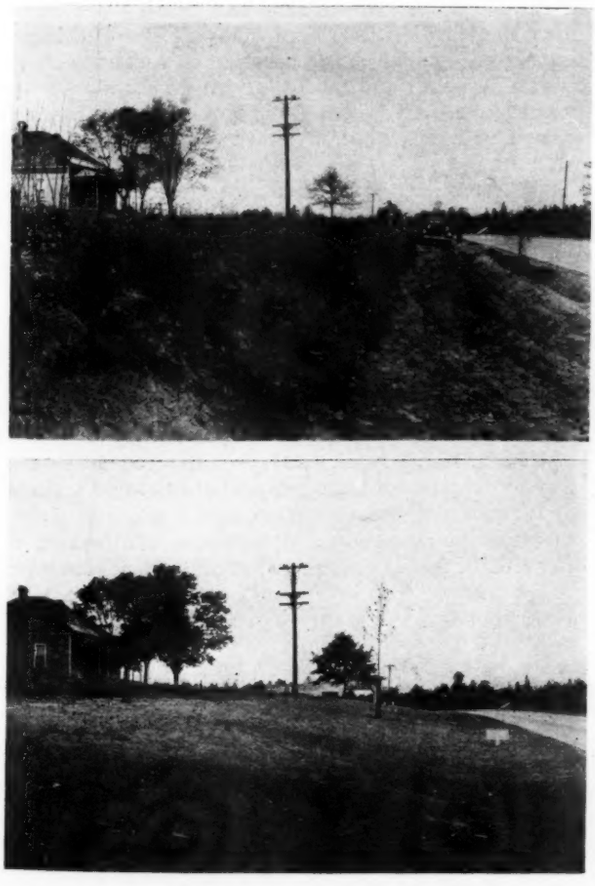
The incinerator burned 4,098 tons of refuse, monthly totals varying from 239.73 tons in August to 391.43 in June. (Princeton University, which contributed 1,063.6 tons during the year, furnished very little during the summer months.) This total yielded 427 tons of ash. The total operation cost averaged 77.8 cts. per ton, or 74.3 cts. omitting the three summer months. Including fixed charges, the cost average at $1.474 per ton. The incinerator has a designed capacity of 48 tons per 24 hrs., and is operated about 10 hrs. daily except Sundays. All leaves gathered from the streets were taken to the sewage treatment plant, where they are mixed with sludge, with the purpose of using the mixture as fertilizer. 1500 cu. yd. of leaves were collected in 1907, sweeping 108 curb-miles, at a cost of $12.62 per curb-mile.



Flattened slope on curve increases sight distance and improves appearance

North Carolina Improves Roadsides for Beauty, Safety and Economy

THE four principal objectives of roadside improvement in North Carolina are (1) to contribute to the safety of the highways and to their economical maintenance; (2) to protect existing natural beauty against improper exploitation and despoilation; (3) to eliminate unsightly features that are found along too many highways, and (4) to retain the natural scenic character of North Carolina by blending the highways into the surrounding landscape and terrain.

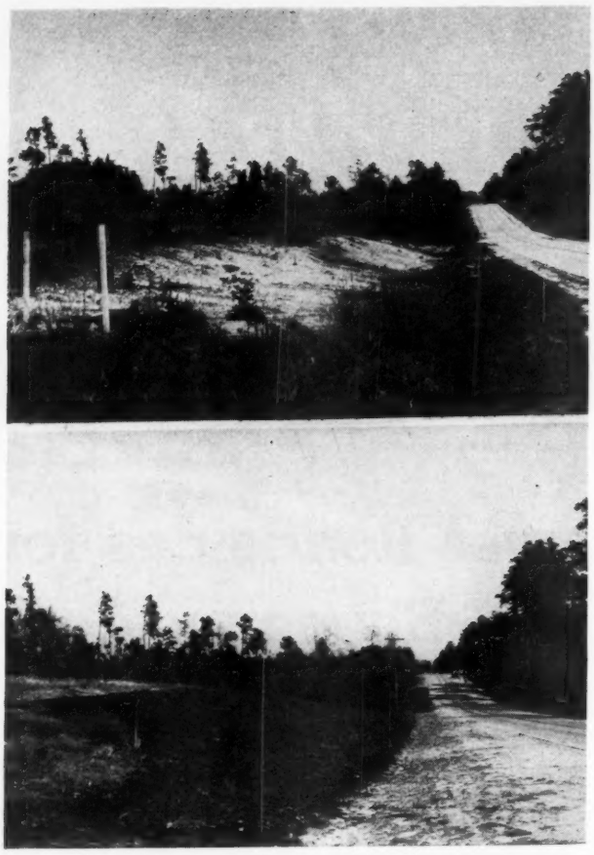


Before and after on U. S. 1, near Sanford

Sharp cuts have been flattened and planted with grass and vines to prevent erosion; ragged and rough areas of barren soil along the right-of-way have been smoothed over and planted to grass; logs, stones, tin cans, stumps, and unsightly advertising signs have been removed from the roadsides. Curves have been cleared of trees on the inside to permit better vision on the part of drivers, and these cleared areas have been lanscaped and planted both to prevent erosion and to make them attractive to the eye.

While this work is being done primarily from a utilitarian and safety point of view, it has resulted in the beautification of the highways wherever it has been done. The planting of trees and shrubbery has been done in such a way as to preserve the characteristic roadside scenery to be found in North Carolina. Native trees and shrubs commonly found in the woods and forests are used, such as dogwood, red-bud, mimosa, longleaf pines, white pines and numerous varieties of oaks. In the clearing and maintenance of the rights-of-way along all North Carolina highways, the maintenance crews have standing instructions to preserve as many as possible of the trees and wild flowers that are of a decorative nature, provided they do not interfere with vision and become a driving hazard.

The cost of the roadside improvement work in North Carolina is borne jointly by the Federal Government and the state and the work is being done only on the Federal Aid highway system. The Federal law requires that one per cent of all Federal Aid funds and one per cent of the state appropriation used to match these funds, shall be used in roadside improvement work. Since this provision became effective, approximately 140 miles of roadside improvement projects have either been completed or authorized, at a cost of $275,000 while for this next fiscal year of 1938-39, six additional projects aggregating about 35 miles have been planned at a cost of approximately $60,000. In addition to these projects, the highway department has cooperated with the Soil Conservation Service in a number of combination roadside and general land improvement projects to demonstrate soil erosion control.



Before and after. maintenance reduced; erosion stopped. U. S. 1, near Norlina.

At present, the highway department jurisdiction does not go beyond the right-of-way, so that it is up to the public and to the landowners to improve the remainder of the roadside picture. In the past there has been much apathy towards this work. Now, however, farmers, landowners and the public generally are taking more and more interest in the natural beauty of the state and many are actively cooperating with the highway department in its roadside improvement and beautification program.

Wherever possible the North Carolina highway department is obtaining easements on land abutting on its rights-of-way, so that it may extend its improvements and restrict the placing of signs. It is also encouraging landowners along the highways to cooperate in beautifying and improving their land and in preserving natural growth.

All of the roadside improvement work in North Carolina is under the supervision of F. H. Brant, landscape engineer of the highway commission.

Swimming Pools in City Parks

The question of the use to which parks may be devoted has arisen in various jurisdictions, and it has been held that municipalities may use parks for tennis courts, baseball grounds, race tracks, tourist camps, golf courses, libraries, memorial buildings, museums, art galleries, zoological and botanical gardens, and other recreational and educational facilities. Park purposes are not confined to tracts of land kept to grass and trees, but extend to the improvement of tracts as places of recreation and amusement of the public. The use to which park property may be devoted may depend to some extent upon the manner of its acquisition. A less strict construction is adopted where a park property is purchased or condemned by a municipality than upon dedications made by individuals. There appears to be no case to the effect that the use of a reasonable portion of a public park for a swimming pool is not a legitimate use for which public parks are created. The South Dakota Supreme Court (Lefevre v. Board of City Commissioners of Brookings, 272 N. W. 795) held that the municipality might construct a swimming pool on city property recently set aside as a park, although the grounds had not been developed.

Arizona's Creosoted Wood Bridges

The Arizona state highway department has prepared a standard design of 19-ft. span center to center of pile bents and 24-ft. clear roadway between hand rails for pressure-creosoted wood bridges. This is capable of carrying the usual H-15 truck loading specified by the American Association of State Highway Officials.

The bents contain four piles each, driven in place or set on mud sills. The caps are rough 12 x 12-in. timbers 26 ft. long. The stringers are 10 lines of 6 x 18-in. x 20-ft. rough sawn timbers which have been sized to an even depth of bearing at each end over the caps. The flooring consists of 2 x 6-in. pieces S1S1E, on edge, spiked together and to the stringers. An asphalt mat surface, 3 to 4 in. thick, is generally placed on the floor for its protection and to provide a continuation of the adjacent road surface across the bridge. A 3-in. plank is spiked to the sides of the bridge floor for the retention of this surfacing. Upon these retainer planks are superimposed 2-in. scupper blocks and an 8-in. curb timber. The latter assembly is bolted through the floor and stringers. A single low heavy rail is carried on 8-in. posts for visibility and for traffic protection.

In general, these creosoted wood structures are built of sawn Douglas fir timbers and round piles of the same species or of southern yellow pine. The larger timbers are incised before pressure treatment to obtain a suitable depth and uniformity of penetration of the preservative. All wood going into these bridges is treated, with the exception of the rails, which are painted white.

The retentions of coal-tar creosote specified by the Arizona State Highway Department for bridge construction vary with the material size and intended use. R. A. Hoffman is bridge engineer, with headquarters at Phoenix.

Proof of Cause of Breaking of Water Main

In an action for damages caused by the breaking of a water main which flooded plaintiff's cellars, the New York Court of Appeals held (Layer v. City of Buffalo, 274 N. Y. 135, 8 N. E. [2d] 307) that too much in the way of evidence of negligence would not be demanded of the plaintiffs, who were not in a position to make a thorough investigation and determne what caused the bursting of the water main, what caused a second break, or whether the first break had been properly repaired. Judgment for defendant was reversed and a new trial ordered.

Sewer System Construction Bonds

The Virginia Supreme Court of Appeals held (Ennis v. Town of Herndon, 191 S. E. 685) that an election approving the issuance of bonds for a municipal sewer system construction was not invalidated by the elimination of sewers to be installed on certain streets which, by the prospectus and plan issued to voters prior to the election, it had agreed to install where the construction of the eliminated sewers proved for economic reasons to be impracticable due to underlying rock.

The Editor's Page

Bids for Engineering Services

About every so often some benighted community publicly solicits bids for engineering services. Three good terms to apply to this practice are (1) hazardous; (2) unprofessional; (3) unethical. We might also add that rarely does anyone get a good bargain out of it.

Most cities have to buy equipment and material on the basis of low bids, but it has repeatedly been held by the higher courts that laws requiring award of contracts to low bidders do not apply to contracts for personal services. When purchasing materials or equipment, quality and quantity can be standardized or definitely specified, so that the price alone is variable. Specifications can be prepared that are fair to most of the manufacturers of such materials or equipment. But when the services of an engineer are to be purchased, it is difficult or impossible to prepare specifications for his qualifications to furnish professional services. To do so would require consideration of his moral and mental qualities, reliability, experience and technical ability.

By this we do not mean to say that no consideration should be given to the matter of cost of the engineer's services, but those factors of reputation, training, experience and professional standing are infinitely more important, and should be given greatest weight by a community when selecting an engineer to spend its money. The fee is a relatively small part of the total cost of the work, and a corresponding weight only should be given to it.

Assessment Instead of Taxes

In January we suggested that cities could reduce taxes by reimbursing themselves for cost of services rendered by collecting rates or assessments from those benefited. An illustration of this has been brought to our attention in the case of Columbus, Ohio. In a designated area of that city street cleaning assessments are levied against property owners at rates varying from 3 cents a front foot on residential streets to 49 cents in the market district, 4 cents being common in most residential sections. The city officials now are considering extending this practice over the entire city, with a rate averaging 4 cents for at least 7 clean-ups a year between April 1 and October 15 in most of the streets and slightly more in the downtown area.

Making Water Wetter

Oil and water are reputed not to mix, yet it is the petroleum chemist who has succeeded in producing sulphonic substances that are now used to make wetter the water used in scouring and cleaning wool. As is not generally known, the difficulty in wetting wool is comparable to wetting the well-known duck's back. The result of this better cleaning of wool is most pleasing to the dyers, dressmakers, etc., but no doubt is equally painful to the operator of the local sewage treatment plant which has to take care of the resulting waste. Maybe the petroleum chemist will tell Mr. O. P. Rater what to do about it.

A Pleasing and Sensible Independence

In writing to us the other day regarding the contruction of a contemplated water works system, the mayor of a small community said: "If this project is done at the present, it will be handled on a strictly municipal basis, without Federal or State aid or regulation."

That community should be congratulated on its mayor. Without being insensible of the many benefits that PWA and WPA have contributed, the time has about come when local communities should stand on their own feet. About all that is needed in the overwhelming majority of cases is the will to do so.

Both WPA and PWA have been exceptionally hard on the local engineers, without any corresponding benefit to anyone else. As an engineer writes us: ". . . the smaller cities have learned that if they hold out and plead poverty long enough, the government will do all, even to furnishing the engineering, which, unfortunately, is not always of the highest standard. The private and independent practitioner, except in the largest cities, is in a bad way. He cannot cope with this form of governmental competition."

Being familiar with both work done on the strictly municipal basis and with that done under WPA, the writer is pretty firmly convinced that the former is preferable. The labor can be selected from worthy men who are not on relief, but who need work and will do a day's work; these men can be paid a reasonable rate and worked reasonable hours so that they can earn a living wage; the same can be applied to the engineer. The cost is but little more, if any; the job can be completed on schedule; there is no lack of skilled—really skilled—men. Those who have had experience in both types of work will realize many other differences which cannot be translated into words.

Sanitation for Wading and Swimming Pools

One of the manufacturers of chlorinating apparatus has given us a ready-made editorial. He says: "Unsterilized swimming pools have long been known to transmit contagious diseases. . . . Many states have adopted regulations governing swimming pool operation and the general public is becoming increasingly conscious that so-called wading pools should be kept up to certain sanitary standards. . . . Although these recreational places for children are designed for wading, actually there is more or less bathing in them. Children in their play are knocked down or fall, resulting in true Baptist total immersion, with incidental hazards of infection."

We have always felt that sanitary control of swimming and wading pools is highly important. If such sanitary control is not enforced, eye, ear, nose, throat and skin troubles run rampant. Admittedly a difficult problem, swimming pool sanitation deserves proper attention by authorities.

The Operation of Water Treatment Plants

Prepared by W. A. Hardenbergh and Consulting Staff

THE only reason for treating water is to remove the undesirable qualities it contains. These may include (1) impurities that are dangerous to health, for instance, bacteria which are disease causing or which are so commonly found in company with bacteria capable of causing disease as to indicate dangerous contamination; (2) Turbidity, color, taste or odor in the water which tend to make it unpleasant to drink (or the factors which cause these); (3) Hardness, alkalinity, iron, manganese or other characteristics which make the water more or less unfitted for domestic or industrial uses or affect the piping of the distribution system.

As a preliminary to treatment it is necessary to know what kind of impurities are present, and in what quantities. This is determined by means of various tests, which are used not only for showing what treatment is necessary, but also for indicating how effective such treatment is in removing the impurities. Tests are therefore doubly necessary, in that they both determine the need for treatment and measure the results of such treatment.

The Metric System. — In making tests, the units of the metric system are ordinarily employed, and the student must be familiar with these. Except to gain a preliminary idea as to the amounts or volumes involved, there is no need to transpose metric units into pounds, ounces, gallons, inches, etc.

In the metric system, the standard unit of volume is the liter (slightly more than 1 quart), which is equal to 1,000 cubic centimeters (abbreviated c.c.); and also to 1,000 milliliters (ml.), which unit is now generally used instead of the cubic centimeter.

The standard unit of weight is the gram, which is the weight of 1 c.c. or 1 ml. of water. A kilogram equals 1,000 grams (about 2.2 pounds); 1 gram contains 1,000 milligrams (mg.). It is convenient to remember that 1 mg. per liter equals 1 part per million (p.p.m.).

To summarize:

1 liter=1,000 c.c.=1,000 ml.

1 kilogram=1,000 grams=1,000,000 mg.

1 liter of water weighs 1 kilogram.

The centigrade system of measuring temperatures is used in addition to the Fahrenheit scale commonly employed in this country. In the centigrade (C) scale, freezing is at 0° and boiling at 100°; in the Fahrenheit (F) scale, freezing is at 32° and boiling at 212°.

To change F to C: Subtract 32 from the F reading, divide the remainder by 9 and multiply this answer by 5. Example: 95° F. Subtract 32 leaving 63; divide by 9 equals 7; 5×7=35° C. Ans. To change to F.: Divide by 5, multiply by 9; add 32. Example: 20° C. Divide by 5 equals 4; 4×9=36; 36+32=68° F. Ans.

Measuring Amounts of Chemicals.— There are three common methods of measuring the amount of chemicals in water. These are: grains per gallon (gpg.); parts per million (p.p.m.); and pounds per million gallons.

Since there are 7,000 grains in an avoirdupois pound, 1 grain per gallon equals 1 pound in 7,000 gallons or 1,000,000÷7,000=142.9 pounds per million gallons. A gallon of water weighs 8 1/3 pounds; therefore 1 gpg =142.9÷8 1/3=17.1 p.p.m. Thus

1 gpg=17.1p.p.m=142.9 pounds per m.g.

1 p.p.m.=.058 gpg=8.33 pounds per m.g.

1 pound per m.g.=.007 gpg=.12 p.p.m.

When Imperial gallons are used, these figures change. The U. S. gallon equals 0.83 Imperial gallon. One grain per Imperial gallon equals 14.3 p.p.m.

Standards of Quality of Water.—It is necessary to have certain standards by which to judge the quality of the water. For some types of impurities there can be no set standards which are desirable or practicable for all localities. Hardness, for instance, is judged by local conditions, and a water that would be considered hard in New England might be thought a soft water in North Dakota. But for those impurities that affect health, there are and should be strict standards that apply in all places.

The United States Treasury Department has formulated a set of standards which have been quite generally adopted. Essentially these require:

The water must be obtained from a source free from pollution or adequately protected against such pollution. The water supply system must be free from sanitary defects, in wells, reservoirs, treatment plants, distributing systems, etc.

In regard to bacterial quality, the presence of coliform bacteria is rigidly restricted, and definite requirements are laid down in regard to these. Physically, the water must be clear, colorless and odorless, pleasant to the taste, and without any excessive amount of dissolved minerals. The common standards in regard to most of these are given in connection with the outline of tests hereafter; in others, no fixed limits can be applied, because acceptable and usual standards vary in the different parts of the country. Treasury Department standards are contained

W. W. Towne **W. H. Weir** **F. E. Stuart**

Some of the men who aided in preparing this article

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in Reprint 1029 of the Public Health Reports, which can be obtained from the Superintendent of Documents, Washington, D. C., for 5 cents.

Laboratory Equipment.—A laboratory and some laboratory equipment are required in every plant. It is not necessary that the laboratory be large, nor the equipment costly. What is needed depends upon the tests that are to be performed, and these, in turn, depend upon local conditions. A laboratory layout for a small plant and a list of the equipment needed to make the various tests can be obtained from your State Board of Health by addressing the State Sanitary Engineer, or will be furnished by the Editor of this magazine without charge. *Standard Methods of Water Analyses* can be obtained from the American Public Health Association. Orders will be forwarded to the publishers of this book by the Editor of this magazine. Other books of value are: *Analysis of Water and Sewage,* by Theroux, Eldridge and Mallman; and *Water Supply and Treatment,* by Hoover.

Procedure in Testing

Standard Methods should be followed in detail, and exactly. Some of the tests are presented hereafter in a somewhat simplified form, including the tests for turbidity, color, odor, pH, alkalinity and acidity, carbon dioxide, hardness, and residual chlorine, and the procedure in certain microscopical examinations. Procedure in bacterial examination will be discussed, but it is recommended that the details and technique of these examinations be learned through attendance at short schools or other courses of instruction that are provided in almost every state. Other tests of a similar nature, as those for dissolved oxygen, chlorides, nitrates and nitrites, etc., also should be learned by actual instruction and practice.

(a) Turbidity

Particles of soil carried in suspension in the water cause a muddy or turbid appearance. Such water is objectionable, and must be treated before use, though turbidity alone does not affect health.

The amount of turbidity in water before treatment is important in determining dosages of chemicals for coagulation. There should be almost no turbidity in water that has been filtered, as proper treatment will remove practically all of it.

The upper limit of turbidity that will not cause complaints from consumers is about 5 p.p.m.; that is, five parts by weight of solid matter to a million parts of water.

Prof. A. P. Black **Paul Weir** **H. E. Miller**

These men also contributed valuable suggestions

Method of Determining Turbidity.—To meet varying conditions, three methods of testing the amount of turbidity are available. These are (1) by means of the turbidity rod of the U. S. Geological Survey, (2) by means of the candle or Baylis turbidimeters and (3) by comparison with previously prepared standards. The turbidity rod is used mainly for field determinations; the turbidimeters for laboratory work.

The turbidity rod is about 4 feet long. At the lower end a bright platinum needle or wire 1 inch long and one millimeter (1/25 inch) in diameter projects at right angles to the rod. At the upper end, 1.2 meters (47¼ inches) above the needle is a ring. The lower end of the rod carrying the platinum wire is submerged vertically into the water, the eye being held at the ring. The rod is graduated to show turbidity. When the wire just disappears from view in the water the surface of the water marks on the rod scale the turbidity reading. A turbidity that causes the wire to disappear with a submergence indicated in the scale by 70, has a turbidity of 70, and will be of decidedly muddy appearance. With a turbidity of 70, the wire can be seen when it is not more than about 5½ inches below the surface; with a turbidity of 30, the wire can be seen at a depth of about 12 inches.

The reading should be taken in the open, preferably when the light is good as in the middle of the day, but not in direct sunlight.

The candle turbidimeter consists of a graduated tube so placed in a holder that it is held over a standard candle or electric light, while light is excluded from the sides. Turbidity is determined by pouring the water into the tube until the flame of the candle just disappears from view. The graduations on the tube then indicate the turbidity. After the image of the candle flame has disappeared, removal of 1% of the liquid in the tube should make it visible again. Observations should be made in a darkened room or with a black cloth over the head.

The tube should be kept clean, inside and out; soot from the candle on the bottom of the tube must be removed. The flame of the standard candle tends to increase in size after a few minutes burning, thus causing error. Before lighting, the charred part of the wick should be removed; during the test, it must be kept a constant distance below the bottom of the tube.

The candle turbidimeter cannot be used to read turbidities below about 25. For water with lower turbidities, it is better to obtain results by the Baylis turbidimeter or by comparison with standards.

For preparing standards for determining turbidity by means of compar-

In presenting this text, it is the intention of the Editors of Public Works to give a basic and balanced course covering the fundamentals of water treatment. Of necessity it is elementary in character. It covers those subjects that every operator should know and provides him with an outline on which he may expand his studies. Primarily, the purpose is to aid in preparation for licensing tests to help in advancement in the profession, and to further the production of safe and palatable water.

Those having questions not covered in the text are invited to write to us. Every effort will be made to answer fully all questions submitted, either directly or through other engineers. Comments are invited as a guide to the editors in preparation of future material.

isons, Fuller's Earth is used. Equipment required includes a 200-mesh sieve, a small amount of Fuller's Earth, and 10 or 12 250 c.c. bottles. Sift enough Fuller's Earth to produce at least 1 gram. Add exactly 1 gram to exactly 1 liter of distilled water; mix. The resulting turbidity is 1,000, that is, 1,000 parts per million. This is called *standard suspension*. Its turbidity should be checked with the turbidimeter and adjusted if in error.

On each of the bottles place labels, to indicate turbidity, as 5, 10, 20, 30, 40, 50, etc. Prepare as shown in the table below by placing in each 250 c.c. bottle, a portion of the standard suspension, and filling with distilled water.

Bottle Marking p.p.m. of Turbidity	Add c.c. of Standard Suspension	Add Dist. Water to Fill
5	1.25 ml.	248.75 ml.
10	2.50 "	247.50 "
20	5.00 "	245.00 "
30	7.50 "	242.50 "
40	10.00 "	240.00 "
50	12.50 "	237.50 "
Etc.		

The pipette or graduate used to handle the standard suspension should be rinsed carefully before each portion is measured. The standard suspension solution should be shaken before each portion is withdrawn. As many standards as are desired may be prepared.

Place the water whose turbidity is to be determined in a similar 250 c.c. bottle and compare with the standards. A background of ruled lines of various widths is a help in comparing.

Expression of Results.—According to standard practice, results are recorded as follows:

Turbidity between	0 and	1	to nearest 0.1
1 "	50 "	"	1
51 "	100 "	"	5
101 "	500 "	"	10
501 "	1000 "	"	50
1001	"greater "	"	100

In reporting, therefore, a turbidity of 33 should be reported as 33; a reading of 53 should be reported as 55, and 62 should be reported as 60; a turbidity of 106 should be reported as 110, and one of 518, as 500.

(b) Color

Color in water is due to material that is in solution in the water, as from decaying organic matter in swamps, where it consists of the tannates, gallates and organic acids from leaves and bark, and from plants. An apparent color is sometimes caused by colored matter in suspension, but true color is always in solution.

Color is an objectionable quality, but is ordinarily harmless. Water should not contain more than 5 parts per million of color, as a larger amount is noticeable and may cause complaints from consumers.

Determination of Color.—This test is a simple one. A standard 50 c.c. Nessler tube may be used. This is filled and compared with a series of color standards. The tubes are viewed by placing them on a white surface and looking down on them from above.

Color solutions for comparisons may be made by dissolving potassium chloroplatinate in distilled water, but it is simpler to purchase the standards, either in solution form, or as colored glass discs.

When there is suspended matter in the water, it is impossible to determine the real color, and removal of such matter must precede the color test. Filtering out of the suspended matter produces a decolorizing action; removal of the suspended matter by centrifuging is best.

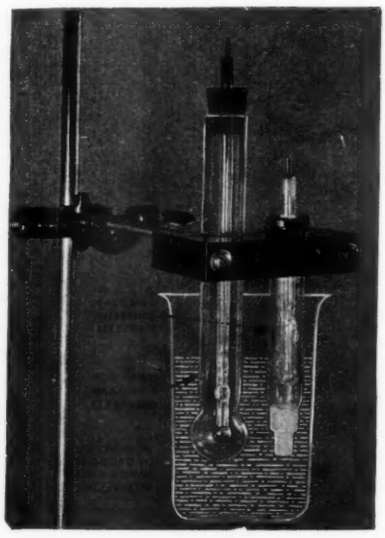
(c) Taste and Odor

Tastes and odors usually occur together. They may be caused by volatile oils produced in the growth or decomposition of algae and diatoms in the water; by the decomposition of vegetable matters; by dissolved gases; by the presence of industrial wastes, etc. See also the section on Taste and Odor Control.

Determination of odor may be made with the water either hot or cold—the former giving the more positive results. The intensity and quality or kind of odor is, of course, a matter of personal opinion, but trained "smellers" will usually agree quite closely.

Cold odor is determined by filling a bottle or flask (capacity about 300 to 500 ml.) half or two-thirds full, with water at room temperature (20° C.), shaking violently, removing the stopper and smelling.

Hot odor is determined by heating about 200 ml. of water in a 500 ml. flask, the neck being covered with a watch glass; bring to 65° C, remove flask from the heater, agitate with a rotary movement, slip the watch glass cover to one side and smell.



A simple form of electrode for measuring pH. (L. & N.).

The intensity of odor is best determined by the "Threshold Odor" test. If an odor is detected in the sample, add 200 ml. of odor free water to 200 ml. of the sample, thus diluting it to 1 in 2. This procedure is repeated, with the next dilution representing 1 in 4, the next 1 in 8, etc., until a second dilution is reached below which odor is not readily detectable. Then starting with the sample of greatest dilution, test the samples in order until one is reached in which odor is just detectable. This is the threshold odor.

Expression of Odor Quantity

Number of Dilutions No odor in undiluted sample	Odor Intensity None	Odor Concentration (0)
0	0	1
1	1	2
2	2	4
3	3	8
4	4	16
Etc.	Etc.	Etc.

If hot odor tests are made, separate dilutions are necessary. Odor characteristics are listed in *Standard Methods*.

(d) Mineral Constituents of Water

Alkalinity, acidity, hardness and other similar characteristics of water are caused by the presence of soluble minerals. There are three general groups—causing (1) alkalinity, (2) salinity and (3) acidity, respectively.

Alkalinity represents the content of carbonates, bicarbonates, hydroxides and occasionally borates, silicates and phosphates. Some of these cause carbonate hardness; some do not. The sodium and potassium carbonates and bicarbonates cause alkalinity, but not hardness. Calcium and magnesium bicarbonates cause a temporary hardness, and calcium and magnesium carbonates cause a hardness that is not removable by heat treatment or lime below about 30 p.p.m. These two forms of hardness are called carbonate hardness.

Salinity represents the content of sulphates and chlorides of calcium and magnesium—the permanent or non-carbonate hardness—and the sulphates, chlorides and nitrates of potassium and sodium, whose presence does not cause hardness.

Acidity represents the content of free carbon dioxide, mineral acids, sulphates of iron and aluminum, etc. None of these affects the hardness but may affect palatability or acceptability for boiler or other commercial purposes or cause corrosion of pipe.

There are two ways of measuring alkalinity or acidity—by the amount of carbonates, bicarbonates, hydroxides

and other alkalinity-causing compounds and also by the intensity. Both are important in water purification.

(e) Alkalinity

The amount of alkalinity is determined by adding a standard acid in measured quantity; the acidity is determined by adding a standard alkali. The amount of acid or alkali required to neutralize the sample indicates the amount of alkalinity or acidity.

The intensity of alkalinity or acidity, that is, the hydrogen ion concentration or pH, is measured by adding a color indicator which has the property of recording by varying color shades the intensity of the alkalinity or acidity; or by use of the equipment which measures pH electrically.

The determination of the intensity of alkalinity or acidity by hydrogen ion concentration is quite generally used. This method is based on the color reactions of various chemicals with waters of different acidity or alkalinity. The test is best performed by using one of the several available pH comparators. A small amount of the water to be tested is placed in a tube—from 5 to 15 c.c.—and the color reagent is added. The color is then compared with glass or similar standards. Thus pH determinations are extremely simple.

The pH scale ranges from 1 to 14; 7 is neutral. Valves below 7.0 indicate acid water; above 7.0 alkaline waters. The degree of intensity of acidity increases as the numbers become smaller: Thus 6.6 is acid, 5.8 more acid, 3.5 still more acid. The degree or intensity of alkalinity increases as the pH numbers increases: Thus 7.6 is alkaline, 8.5 more alkaline and 10.1 even more alkaline.

In general, pH is determined to one decimal point, as 5.6, 7.4, 8.2 or 9.3.

This determination of alkalinity does not give any indication of the *amount* of alkalinity that must be neutralized, except in conjunction with other tests.

To determine the amount of alkalinity (usually called merely "alkalinity") the following apparatus is needed: 1 burette (a graduated glass tube, mounted on a support and provided with a stop cock), a 200 c.c. Erlenmeyer flask, pipettes, and a 100 c.c. measuring cylinder. There is also needed a solution of phenolphthalein indicator, a solution of methyl orange indicator, and a solution of 1/50 normal (N/50) sulphuric acid. All of these can be purchased ready for use from chemical supply houses.

To test, 100 c.c. (or ml.) of the sample is placed in the Erlenmeyer flask and four drops of the phenolphthalein indicator are added. The flask is shaken. If pink or red color appears, the water is alkaline to phenolphthalein. If no color appears, the water contains no carbonate or hydroxide alkalinity. If there is a color reaction add the sulphuric acid solution drop by drop, shaking the flask after each addition, until the color just disappears. The number of c.c. (or ml.) of acid solution used must be noted. The alkalinity to phenolphthalein is 10 times the number of c.c. (or ml.) required to cause the color to disappear. If 3.7 ml. were required, the alkalinity to phenolphthalein is $10 \times 3.7 = 37$ p.p.m.

The sample already used for the phenolphthalein test can be used for the methyl orange alkalinity test; or a new sample of 100 c.c. can be used. To the sample is added 2 drops of the methyl orange indicator. If the solution becomes yellow, there is hydroxide, normal carbonate or bicarbonate present. The N/50 solution of sulphuric acid is added as before until the yellow color begins to turn to orange. The alkalinity to methyl orange in parts per million is equal to 10 times the number of c.c. (or ml.) of sulphuric acid solution necessary to cause the color change. If a fresh sample has been used, and 5.8 c.c. are required, the alkalinity to methyl orange is 58 p.p.m. Methyl orange alkalinity includes also the phenolphthalein alkalinity; hence if the sample previously used for phenolphthalein is used for the methyl orange test, the total amount of acid in both tests is used for computing.

If the water is turbid or colored, erythrosine should be used instead of methyl orange. Results are the same, but with this indicator the color change is shown by the drops of chloroform added, and not by the water.

Procedure is as follows: To 100 c.c. of the water to be tested, add 5 c.c. of neutral chloroform and 1 c.c. of erythrosine indicator. If the water is alkaline, the drops of chloroform will be pink: if acid, the drops will show no color. Add standard N/50 acid solution, as for methyl orange, if alkalinity is present, shaking vigorously until the color of the drops change from pink to colorless. Multiply the number of c.c. of N/50 acid solution required by 10 to determine the alkalinity of the water.

References hereafter made to methyl orange alkalinity apply equally to erythrosine alkalinity.

From the results of these tests, a great deal of information can be obtained regarding the mineral content of the water. But it is desirable first to mention the three types of alkalinity. These are bicarbonate alkalinity, which exists in the range below pH 9.4; the carbonate alkalinity with no CO_2 present which exists in the range above

A comparator that uses glass color standards.

pH 8.3, thus overlapping the bicarbonate alkalinity between pH 8.3 and pH 9.4; and the caustic or hydroxide alkalinity, found above pH 9.4, in which no bicarbonates and no CO_2 are present.

The phenolphthalein and methyl orange tests are based on the facts that phenolphthalein is colorless when CO_2 is present, but shows a pink color when this gas is removed, which occurs at about pH 8.3; and that methyl orange is orange in the presence of strong acids, but turns to yellow when the acidity is less—above about pH 4.4. In the later case, the acid solution, as it is added, neutralizes alkaline bicarbonates in the water; and after these are neutralized, a very small additional amount of acid causes the pH to shift to about 4.4 and the yellow color of the indicator then turns to orange.

If the alkalinity to phenolphthalein is 0, that is, there is no color reaction to the addition of the phenolphthalein indicator solution, there is no caustic alkalinity and no carbonate alkalinity, but the alkalinity to methyl orange as shown by the test represents the bicarbonate alkalinity.

Example: Alkalinity to phenolphthalein is 0.0 p.p.m.; and to methyl orange is 18.5 p.p.m. Therefore, caustic alkalinity is 0; carbonate alkalinity is 0; and bicarbonate alkalinity is 18.5.

When the alkalinity to phenolphthalein is less than one-half the alkalinity to methyl orange, there is no caustic alkalinity; the carbonate alkalinity is twice the phenolphthalein alkalinity; and the bicarbonate alkalinity is the methyl orange alkalinity minus twice the phenolphthalein alkalinity.

Example: Alkalinity to phenolphthalein is 28.0 p.p.m.; and to methyl orange 86.0 p.p.m. Therefore, caustic alkalinity is 0; carbonate alkalinity is 56.0 p.p.m.; and bicarbonate alkalinity is $86-(2\times28)=30.0$ p.p.m.

When the phenolphthalein alkalinity is exactly one-half of the methyl orange alkalinity, the caustic alkalinity is 0, the carbonate alkalinity is the same as the methyl orange alkalinity, and the bicarbonate alkalinity is 0.

Example: Phenolphthalein alkalinity is 72.0 p.p.m. and methyl orange alkalinity is 144.0 p.p.m. Therefore, the caustic alkalinity is 0.0 p.p.m.; the carbonate alkalinity is 144.0 p.p.m.; and the bicarbonate alkalinity is 0.0 p.p.m.

When the phenolphthalein alkalinity is more than one-half of the methyl orange alkalinity, caustic alkalinity is twice the phenolphthalein alkalinity minus the methyl orange alkalinity; the carbonate alkalinity is twice the difference between the phenolphthalein and methyl orange alkalinities; and the bicarbonate alkalinity is 0.

Example: The phenolphthalein alkalinity is 150 p.p.m.; the methyl orange alkalinity is 196 p.p.m. Therefore, the caustic alkalinity is $2\times150—196=104$ p.p.m.; the carbonate alkalinity is $(196—150)\ 2=92$ p.p.m.; bicarbonate alkalinity is 0.

When the phenolphthalein and methyl alkalinities are the same, all the alkalinity is caustic alkalinity and carbonate and bicarbonate alkalinities are 0.

(f) CO_2 Determination

To determine the free CO_2 content of the water, the same apparatus is required as for determining alkalinity; also the phenolphthalein indicator and a solution of N/44 sodium hydroxide, which can be purchased ready for use. To 100 c.c. of sample, 10 drops of the phenolphthalein indicator are added and then the sodium hydroxide solution, drop by drop, stirring the sample meanwhile, until a faint pink color is produced. The free CO_2 in parts per million equals 10 times the number of c.c. of the N/44 sodium hydroxide solution used. If an N/50 solution is used, the multiplier is 8.8.

The total acidity is obtained by adding 4 drops of the phenolphthalein indicator to 100 c.c. of the water which has been placed in a white dish or in a flask on a white surface. The N/44 sodium hydroxide solution is then added until a pink color is obtained. The total acidity in parts per million of calcium carbonate equals 11.4 times the c.c. of sodium hydroxide used. If an N/50 solution is used instead of the N/44, the multiplier is 10 instead of 11.4.

Acidity is reported as the parts per million of calcium carbonate.

Cost of Equipment for Tests.—The burette (50 c.c. capacity, with 1/10 c.c. graduations, and a stop cock), the burette support, a 100 c.c. cylinder, 6 Erlenmeyer flasks, the indicators and the acid solution for determining alkalinity, will cost about $10. This is all that is necessary for determining alkalinity. For determining acidity, additional equipment will cost about $3, unless it is desired to have a somewhat more elaborate burette. A very good set can be purchased, that will be suitable for all these tests, for about $15.

In addition, a pH comparator and a copy of *Standard Methods of Water and Sewage Analyses* should be available. The cost for the pH set depends somewhat on the type selected. For $35 to $50 it is possible to purchase the pH set, *Standard Methods,* and all of the equipment listed above.

(g) Hardness

As already stated, the calcium and magnesium compounds cause hardness. Formerly hardness was classified as temporary (which can be removed by boiling) and permanent (which cannot be removed by boiling). These classifications are best replaced by the terms carbonate and non-carbonate hardness, the reason being that, in the usual methods of softening by the addition of lime, soda ash, etc., treatment is based on these characteristics.

Carbonate hardness is caused by the presence of calcium and magnesium bicarbonates, which compose the true temporary hardness removable by boiling; and also by the presence of calcium and magnesium carbonates, which are not removable by boiling below about 30 p.p.m. Non-carbonate hardness is caused by calcium and magnesium sulphates and chlorides, and is not removable by boiling.

Determining Hardness.—For an accurate determination of hardness it is necessary to determine the amounts of calcium and magnesium in the sample, which requires a lengthy chemical procedure. Training in this is available at various of the Short Schools conducted by many of the State Boards of Health. At least one device is on the market for measuring the hardness. For approximate measurement of the hardness, the soap test can be used, though what this actually measures is the soap destroying power of the water.

Procedure.—A burette for measuring small quantities, a 250 c.c. glass stoppered bottle and a quantity of standard soap solution are required. The burette used in alkalinity and acidity determinations may be used, if properly washed. Standard soap solution may be purchased ready for use. Test the *lather factor* by placing 50 c.c. of recently boiled and cooled distilled water in the bottle, and adding soap solution 0.1 ml. at a time, and shaking. Continue until a lather forms that will remain unbroken for 5 minutes. This usually requires 0.5 to 1.5 ml. of soap solution. Note this as the lather factor.

Place 50 ml. of the water to be tested in a similar bottle and add the soap solution 0.2 or 0.3 ml. at a time, shaking vigorously and noting the lather formed. As soon as the lather breaks, add more soap solution; and shake again. When a lather forms, and remains unbroken for 5 minutes, note the reading on the burette and note the amount of soap solution used. After 5 minutes, add 0.5 ml. of soap solution and shake. If a 5-minute lather does not then appear, the first result was a false end-point due to the presence of magnesium, and the addition of soap solution and shaking should continue until a true lather is formed.

From the ml. of soap solution used, subtract the amount of soap required to form the lather factor and multiply the remainder by 20 to obtain the hardness by the soap method.

(h) Residual Chlorine

After a water has been chlorinated, the presence of residual chlorine can be determined by the orthotolidine or the starch iodide tests. The former enables the operator to determine *how much* chlorine remains in the water; the latter indicates only that chlorine is present. The former is therefore generally more valuable and is more widely used.

Procedure with Orthotolidine. — A standard orthotolidine solution is furnished by makers of chlorinating apparatus and by laboratory and chemical supply houses. Using a Nessler tube or a 4 oz. bottle, fill with the water to be tested, allow to stand 10 minutes, and add 1 c.c. of orthotolidine solution. Shake, and allow the mixture to stand 5 minutes; the resulting color, if any, indicates the amount of residual chlorine in the water. A very light yellowish color indicates about 0.1 p.p.m., and the color deepens to orange with the increase of chlorine. Color standards are therefore necessary in order to read closely the amount of chlorine present. It is best to use one of the several excellent chlorine comparators, as these permit quick and accurate readings. Directions for use are supplied by the manufacturers.

When ammonia and chlorine are used in the treatment of the water, or when iron or manganese are present in sufficient quantity to interfere with the test, modifications are necessary in the procedure.

With Ammonia-Chlorine. — When both ammonia and chlorine are applied to the water, a longer period is necessary for the color to develop after the

orthotolidine has been added. Instead of the 5 minutes when chlorine alone has been applied, a 10 to 30 minute period is necessary.

With Iron and Manganese. — If either of these minerals is present, a false color reaction occurs with orthotolidine, thus making the test for residual chlorine unreliable.

Since residual chlorine rarely persists for as much as 24 hours, two samples may be collected each day, one of which is tested at once and the other allowed to stand for 24 hours. When the two samples have been collected on the succeeding day, a test is run on one of these and also on the sample held over from the preceding day. Thus two tests are made each day—one on a sample just collected, the other on a sample held over from the preceding day. The apparent chlorine content of the latter is subtracted from the apparent chlorine content of the former to secure the approximate true residual.

Another method is to collect two samples; test one, and boil the other until about 25% of it is boiled off. Bring up to the original volume with distilled water, cool, test and subtract the apparent residual chlorine content of the boiled sample from the first sample. The boiling drives off the residual chlorine; also, it sometimes affects the iron and manganese compounds, so that strictly accurate results are not obtained, but the errors are not usually great enough to be important.

Starch Iodide.—By this test, the presence of chlorine in the water is indicated by a faint blue color. The reaction takes place with a chlorine residual of 0.10 to 0.15 p.p.m. and is therefore adequate to indicate a satisfactory residual. A rather deeper color is obtained with higher chlorine residuals. But the test is not really a quantitative one.

A starch solution is purchased or made up in accordance with directions in *Standard Methods;* in addition to this, some crystals of potassium iodide (the powdered form may be used), and a Nessler tube, bottle, or test tube are needed.

After the sample to be tested has stood for 10 minutes, add 2 or 3 crystals of potassium iodide, and 10 to 20 drops of starch solution. Shake, hold over a white surface and look down through the sample. A blue color appearing within 5 minutes indicates the presence of chlorine. Color obtained after the 5-minute period should be disregarded. A dark blue indicates that the chlorine dosage is probably unnecessarily large. No color indicates that the chlorine dosage should be increased.

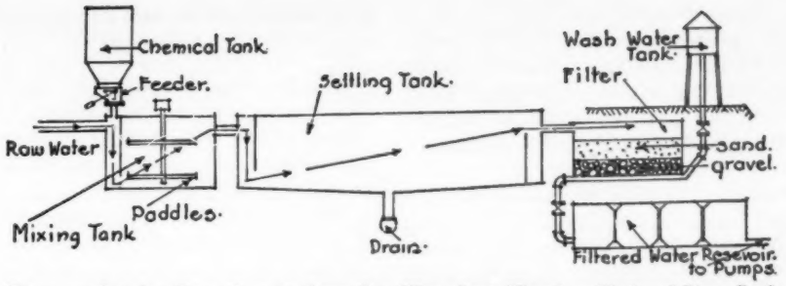


Diagram showing flow of water through a filter plant: (Courtesy National Lime Ass'n. and Charles P. Hoover).

(i) Bacterial Examination

Bacteria are very small organisms, so small that a special unit of length has been devised to measure them. This is the micron (represented by the Greek letter *mu,* which is .001 millimeter or about 1/25,000 inch long. Bacteria normally found in water supplies are from 1 to 4 microns long and about ¼ as thick. Because of their very small size, special methods are necessary in order to find and identify them.

One method of classifying bacteria is by shape. Under this method there are three general types: *Cocci,* which are round or spherical; *Bacilli* which are rod-shaped, like a cigar; and *Spirilla,* which are spiral, like a corkscrew.

For the water works operator or superintendent or sanitary engineer, concerned primarily with preventing water-born disease, there are two broad classifications which are *pathogenic*—disease bearing or disease producing—and *non-pathogenic,* which do not produce, cause or convey disease.

Non-pathogenic bacteria cannot be ignored entirely, because the presence of certain of these is strongly indicative of the possibility that disease bearing bacteria also are present. For instance, typhoid bacteria (B. typhosi) are very difficult to find in water, milk, etc., even when present, so that the usual method of procedure is to test for the coli-aerogenes group, which are constantly present in the human intestines and in urine and feces. If such bacilli are found it is practical proof that the water or milk is contaminated with sewage; and if sewage contamination is present, it is only a matter of time before typhoid baccili will enter and cause disease. The coli-aerogenes group, however, cause no disease and are not harmful.

It is for these reasons that reports of bacterial examinations of water shows the results of tests for coli, and if these are present the water is condemned as bad, even though no examination has been made for B. typhosi.

Bacteria multiply very rapidly by dividing so that a single bacterium, under favorable conditions, will produce many thousand others in the course of 24 hours. Temperature is important; for the organisms, such as coli and typhosi, which live in the body, body temperatures are most favorable, that is, around 98° F or 37° C, but multiplication takes place even at much lower temperature. A temperature of about 135° F kills most of these bacteria, but does not affect certain other forms.

While low temperatures are unfavorable to bacteria, even freezing will not kill all of them, and typhoid bacteria have survived for months in ice. Therefore the use of ice from contaminated water is dangerous.

Bacterial Examinations.—There are three important steps in examining water for bacteria: These are: (1) collection of the sample; (2) determining the total number of bacteria; (3) determining the presence and total number of the coli-aerogenes group.

Samples must be collected in a clean, sterile, glass-stoppered bottle, from 4 to 8 ounces in capacity. Laboratories will furnish such bottles. Samples collected in other types of containers are valueless. When taking a sample from a faucet (which should be flamed), the water should be allowed to run until water is drawn from the main. When drawing from a pump, or hydrant, the sample should be taken only after water from the main, well or reservoir is being drawn. In the case of a lake or stream the stopper is removed, the bottle placed beneath the surface and filled with a sweeping motion so water touching the hand will not enter the bottle.

Immediately after filling, the stopper is replaced, covered with tinfoil, paper or cloth and tied in place. Examinations should be made within 6 hours for impure waters and 12 hours for fairly pure waters. If examinations cannot be made within this period, the sample must be kept cold—between 40° F and 50° F. Even then changes may take place in the sample, as multiplication of the bacteria.

The total number of bacteria is determined by mixing the sample water with liquefied culture media and placing in a petri dish. This is then placed in an incubator for 24 hours, if the temperature is held at 37° C or for 48

hours if the temperature is 20° C. Each bacterium in the water multiplies under those conditions into a colony, which is visible without a microscope. Thus by counting the colonies on the culture media in the petri dish, the number of bacteria is known.

The examination for coliform bacteria is made by adding small portions of the water to tubes containing lactose broth. The formation of gas in these tubes in 24 or 48 hours indicates the presence of some of the coli-aerogenes group of bacteria, and casts decided doubt on the quality of the water. Further tests are available for confirming the presence of these bacteria, and even for differentiating between fecal and non-fecal types.

The above is but a brief outline of the procedure, which involves careful sterilization of all apparatus, exact dilutions, etc. These cannot be learned from any text. Attendance at Short Schools or other courses, or work in a laboratory is necessary before reliable results can be obtained.

The microscope is used in the examination of water for the confirmation of suspected bacteria, but even more in the identification of algae and other aquatic organisms. This latter subject will be discussed in greater detail in connection with algae and taste and odor control, in a later section of this text.

Standards, Limits and Interpretation of Analyses

The Treasury Department Standards previously referred to include bacteriological quality, which is normally covered in Short Schools and operators' courses; requirements as to source and protection; and physical characteristics. These latter include: Turbidity (in general not to exceed 5); color (preferably less than 10); odor (none); lead (not over 0.1 p.p.m.); copper (not over 0.2 p.p.m.); zinc (not over 5.0 p.p.m.); sulphate (should not exceed 250 p.p.m.); magnesium (should not exceed 100 p.p.m.); total solids (preferably more than 300 p.p.m. but not over 1000 p.p.m.); chlorides (not over 250 p.p.m.); and iron (not over 0.3 p.p.m.). There should be no caustic alkalinity nor odor or taste of free chlorine; and the carbonates of sodium and potassium taken together and calculated as normal calcium carbonates should not exceed 50 p.p.m.

Interpretation of analyses, as for instance the meaning of the presence of nitrites, nitrates, chlorides and other compounds cannot well be covered in this text, which is intended to be purely elementary in character. Additional information covering these and many other points will be treated in a text to be available shortly, which will supplement the present one.

How Diseases Are Spread by Water

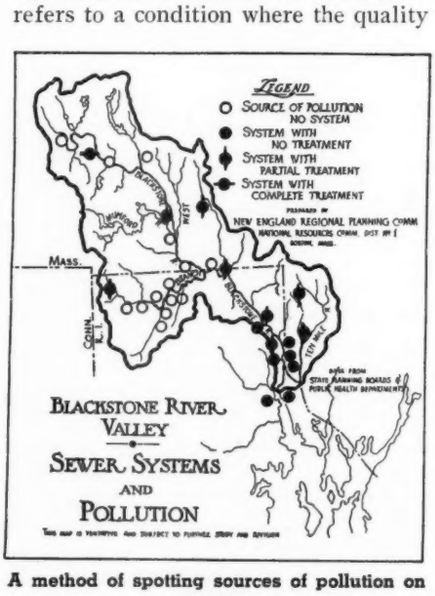
Impure water may be the cause of spread of typhoid fever, dysentery and cholera, and also of certain variations of dysentery, as diarrhea, enteritis, etc. In the United States, typhoid and dysentery and their variations are quite common; cholera does not exist in sufficient amount to be a health menace, if at all.

Method of Spread.—All of these diseases are spread in the same manner. The bacteria causing them are discharged in the urine or feces of persons suffering from these diseases, or of carriers. Carriers are persons who have suffered from one or more of these diseases and have recovered, but continue to discharge the bacteria capable of carrying the disease to others.

The body wastes of such persons, if improperly disposed of, may find their way into the water supply. Even when properly disposed of, as into a sewer system, cross-connections or leaking sewers may infect the water supply. Unless the methods of treatment remove or destroy these bacteria, the consumers are likely to contract disease.

For this reason, particular attention should be paid to the protection of the water supply against contamination or pollution; and also to providing a continuous and safe treatment of the water.

Contamination and Pollution of Water.—The words "pollution" and "contamination" are often used interchangeably, but in this article they will be used as follows: *Contamination* refers to a condition where the quality of the water has been affected, but the appearance has not. *Pollution* affects appearance, and may affect quality also. For instance, the discharge of a small amount of sewage from a leaking cesspool might not affect the appearance of the water, but would make it unsafe to use through contamination. The discharge of wastes from a dye plant or a creamery would discolor the water and would be termed pollution.



A method of spotting sources of pollution on a map.

For most water works, the problem of preventing these is a broad and important one. It covers the protection of watersheds to prevent the access of contaminating or polluting substances to the water supply; and also the protection of the water after it has been treated. In this article only the former will be considered.

Surface Supplies.—The man in charge of a water works system should be familiar with the area from which the water is drawn. In a small supply, he should know personally every acre of the watershed. In a supply drawn from a large river, this detail knowledge is not possible, but collection of certain information is almost a necessity.

A map of the watershed should be maintained on which is spotted every source of actual or potential contamination or pollution, as sewer systems, industrial plants, mines or other factors that may affect the quality of the water. Records should be maintained showing the kind of material discharged, the volume, variations, times of discharge and other pertinent information. If the effects on the water supply are known, adequate measures to remedy these can often be taken; or in cooperation with manufacturers or officials palliative measures may be adopted which will reduce the difficulties due to such wastes.

In the small supply where the watershed area does not exceed a few square miles in extent, a large scale map and pins may also be used to show all existing or possible sources of contamination or pollution. A sanitary survey of the watershed is, of course, one of the very first jobs to be done; in fact, before the area was selected as a source of supply, this should have been done in a painstaking manner and all danger areas carefully recorded.

In most states, there are adequate laws to protect water supplies. These provide that toilets, cesspools, etc., cannot be maintained near lakes and streams and if located on the watershed they must be of certain approved types of construction and must be properly maintained. Copies of regulations covering these points are available on request to your State Board of Health.

Hunting and fishing on watersheds are sometimes permitted. The desirability of doing this depends on local

conditions. For the smaller communities, it is probably better to prohibit, so far as possible, all such uses of the water supply area; also skating. Where hunting and fishing are permitted, it should be by permit only. In very rare cases, if at all, is swimming permissible.

Storage reservoirs are not usually fenced, but distribution reservoirs should be covered. When fenced the bottom 2 feet of the fence should be of close mesh to prevent the entrance of frogs, newts or salamanders which may thus enter the distribution system and cause complaints from consumers.

Springs and Wells.—Springs should be protected from all surface wash by means of a tight concrete structure extending to rock, or for at least 6 to 10 feet into the ground and one foot above ground. It is preferable to cover the structure; or if not covered it should be protected by a fence as previously mentioned. Overflow pipes should be screened and so built that in times of flood or high water, surface water will not back up into the spring.

The principal sources of danger in wells, aside from the quality of the water intentionally drawn from them, are leaky tops or casings. Poorly constructed tops may permit entrance of surface water; leaky casings, if near the ground surface, may also permit contaminated surface water to enter.

Most State Boards of Health have standard plans showing approved construction details for heads or tops for wells, which are available on request.

Wells should be protected against high water, so that floods will not affect them. Suction lines from wells to pumps should not be laid close to sewers or cesspools.

An Outline of Treatment Methods

Processes of treatment are of four general groups: (1) The removal of bacteria, especially those dangerous to health, (2) the removal of suspended matter, such as turbidity or muddiness, (3) the removal of objectionable dissolved impurities, as hardness and iron, (4) the removal of taste and odor.

These are accomplished by screening; sedimentation, with or without the aid of coagulants; filtration through sand; treatment with lime or other chemicals; aeration; chlorination; and by other processes designed to aid these, or to meet special situations.

Intakes and Screens

Intake structures are needed to draw water from lakes or streams; merely laying the pipe out into the water is not satisfactory, for the pipe may sink into the mud, or may draw sand or debris along with the water. It is desirable that the pipe be protected from movement, and the intake located somewhere near mid-depth of the water. This location avoids floating material, as trees, logs and leaves at the surface; wave action which may stir up sand or mud in the water; and ice; also stagnant water near the bottom, mud, etc.

Intakes vary greatly, according to the size of the water supply, depth and bottom character of the lake, direction and intensity of winds and currents, and quality of the water.

Screen should be placed over the pipe at the intake, or in the inlet structure of large intakes. Generally the screen should be designed only to exclude large objects, since removal and cleaning is not easy. A screen having a mesh of about one inch may be used. This prevents the entrance of large sticks, logs and trash. The mouth of the pipe or entrance to the pipe should generally be flared and the area of the screen openings should aggregate about twice the area of the pipe. A low entrance velocity draws less floating material into the inlet.

It is desirable to have the screens at the intake removable, or other provision made for occasional cleaning. A rake can be used to remove any material caught on the screen. Occasional scrubbing and inspection is desirable.

In northern areas, anchor or frazil ice may cause troubles. Frazil ice consists of small crystals which are carried below the surface by even slight currents and which deposit on intakes or screens. Anchor ice forms directly on objects in shallow water. Metal surfaces are especially subject to ice clogging of this sort.

Occasional reversing of the flow of water from the pipe into the lake sometimes helps in removing ice accumulations. Large openings in the intake and low velocity through the intake reduce ice trouble. A boom of floating timber to create an area of still water around the intake is often helpful, especially in smaller reservoirs. Such a floating boom may also be advantageous in keeping leaves, twigs and other floating material away from the intake.

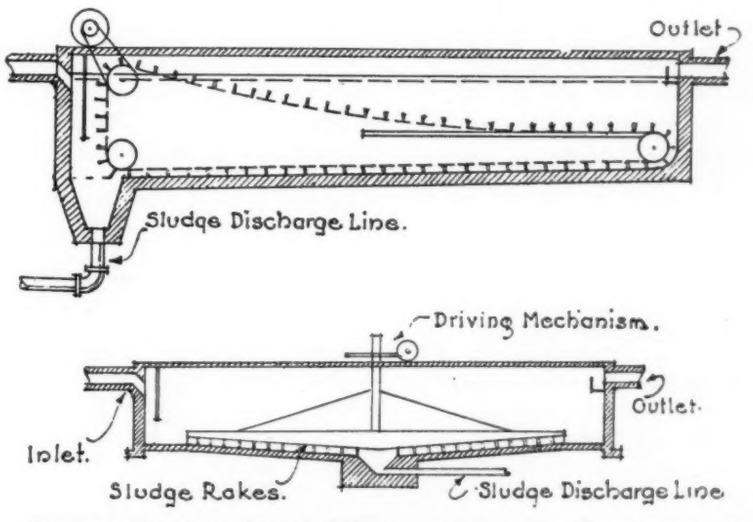
Small oil or kerosene burning units to generate steam quickly are often effective in removing or in relieving frazil or anchor ice clogging. A very small rise in temperature on the exposed surfaces is enough to free them from the ice.

There are several types of screens that can be installed at or near intakes that clean themselves automatically. These consist of an endless or jointed belt of screens which are moved slowly upwards by a small motor. The screened out solids are removed at the top by a small jet of water and dropped into a trough.

This type of screen can be installed at an intake, if electric power is available, or at the treatment plant or reservoir. A ¼ or ⅜ inch mesh screen is commonly used, this being possible because the regular automatic cleaning does not permit clogging. Occasionally a finer screen is used. Denver employs a 60-mesh primarily to remove algae, slimes, etc.

Screens should be in duplicate if of the fixed type, or the moving type described just previously can be used. Double screens are often used.

Operation. — Fixed screens should be scrubbed or squeegeed as necessary to keep them clean; debris collected in them being removed. If possible to do so, the flow of water through them should be reversed or the water shut off



Two types of settling tanks with sludge removal apparatus. (Courtesy National Lime Ass'n and Charles P. Hoover)

and the wash water wasted. Revolving screens may be hosed down or scrubbed from time to time; lubrication should follow the directions of the manufacturer.

Sedimentation and Filtration

These two methods of treatment are generally (though not always) used in combination. It is therefore rather difficult to consider one of them without considering also the other; and the matter is further complicated by the fact that there are two types of sedimentation and two types of filters.

Sedimentation consists in holding the water in, or passing it very slowly through, reservoirs, tanks, or basins. The particles of sand or clay that cause turbidity are about 2.65 times as heavy as an equal volume of water. If the water is held quiescent or practically so, much of this turbidity will settle to the bottom, but currents or eddies will hold it in suspension and prevent it from settling.

Sedimentation basins may be any size—from those that hold the water for only, 1, 2, 3 or 4 hours, up to large reservoirs where the water is stored for weeks or even months. In some cases, sedimentation alone will produce a clear and satisfactory water, except that all water should be chlorinated.

In other sections of the country where clay soils predominate, sedimentation alone will not remove the turbidity. Chemicals are then added—usually aluminium sulphate (commonly but erroneously called alum) or ferrous or ferric sulphate and lime. These chemicals produce an insoluble flocculent precipitate, called "floc," which settles quite rapidly, carrying with it even the very fine particles of clay, and producing a clear water.

Sedimentation without chemicals is called "plain sedimentation"; when chemicals are used to produce a floc and this is afterwards allowed to settle, the process is called "coagulation and settling." These are the two types of sedimentation; they will be considered separately a little later.

The two types of filters are the slow sand filter, which operates at a rate of about 4 to 6 m.g.d. per acre; and the rapid sand or mechanical filter, which operates at the rate of about 125 m.g.d. per acre. These are superficially similar, so far as the construction of the sand bed is concerned, but operate very differently.

The slow sand filter is not suited to treat water that contains turbidity due to clay particles. It is usually employed in connection with plain sedimentation and relatively clear waters. The rapid sand filter is invariably used in combination with coagulation and settling, which process is employed to remove the greater part of the turbidity and prepare the water for the filter.

Plain Sedimentation

There is no standard for the period of sedimentation; that is, there is no fixed time of detention that is applicable to all waters. This depends upon the kind of sediment in the water. The size of the settling basin will depend upon the time required to remove a satisfactory proportion of the settleable matter, and upon the cost of construction. In general, a period of sedimentation longer than 24 hours for plain sedimentation is not economical unless local conditions are such that reservoir construction is cheap.

Operation of Plain Sedimentation Basins.—There is relatively little that the operator can do to improve the operation of plain sedimentation basins, other than to see that the inlets and outlets are kept clean, and that sediment is removed at proper intervals. Modification of inlets and outlets, and installation of baffles should be done only after careful study. The purpose of the inlet is to permit the entrance of the water into the basin with the least possible disturbance or agitation; and of the outlet to allow the water to flow out of the basin without creating undesirable currents or eddies. Baffles or partitions may be of value in creating a full and even flow through the tank, and to prevent any tendency toward "short-circuiting" or direct flow from inlet to outlet. If these structure do not operate properly, careful consideration should be given to any contemplated changes before they are made.

Cleaning Settling Basins. — Most plain sedimentation basins do not have any provision for quick and easy removal of the sediment that accumulates in them. At intervals—usually when the depth of sediment has reached 3 or 4 feet—the basins must be emptied of water and the sand and mud flushed out or removed with scrapers or other tools. More modern basins employ equipment for continuous removal. Such equipment is made by Link-Belt, Dorr, Chain-Belt, Jeffrey and Hardinge.

How Chemicals Are Used in Coagulation and Settling

Basins or tanks for coagulation and settling are usually designed to provide a detention period of 3 to 8 hours —the longer period in those sections where clay soils are predominant, and the water is nearly always turbid. In some places, plain sedimentation is used as a preliminary treatment, as much of the suspended matter can be removed, and the amount of chemical required is reduced.

In coagulation, aluminum sulphate or other suitable chemicals are added to the water. These react with materials present in the water (or with each other) and after a few minutes a flocculent and gelatinous precipitate forms. This attracts or envelops the finely divided particles of clay, silt or organic matter, and absorbs coloring material, forming particles of floc varying in size from those barely visible to feathery flakes. These floc particles, being large, settle quite rapidly and completely, leaving a clear water.

Coagulation is always desirable, as a preliminary to filtration, regardless of the turbidity of the water. It is not a complete process of treatment, being used only for preparing the water for filtration through rapid sand filters.

The dosages of chemical required varies with the amount and kind of turbidity present, with the alkalinity or acidity of the water, with its pH value, with the temperature, and with other factors. Thorough mixing of the chemical with the water, and an adequate period of reaction and of settling are necessary for economy and good results.

Effects of Temperature.—While the results vary with different chemicals, it is generally the case that slightly more coagulant is required at temperatures below 35°F to 40°F and above 65°F to 70°F. Chemical reactions are always slower and less complete at low temperatures, while at the higher temperatures there is sometimes a reabsorption of the floc.

Effect of Alkalinity, Acidity and pH.—The effect of these factors depends upon the type of coagulant used. Each one has its reaction range within which it performs most successfully. These factors will be discussed in connection with each chemical.

Aluminum Sulphate. — Aluminum sulphate, usually called filter alum, and the chemical most commonly used in coagulation, has the formula $Al_2(SO_4)_3$, 18 H_2O. In order to form a floc, alkaline carbonates (calcium, sodium or magnesium carbonates) must be present in the water, and if these are not present, lime or soda ash must be added to supply them artificially.

With alkaline carbonates present, the reaction when alum is added is as follows:

$$Al_2(SO_4)_3 + 3\,Ca(HCO_3)_2 = 3\,Ca\,SO_4 + 2\,Al_2(OH)_3 + 6\,CO_2$$

aluminum sulphate + calcium bicarbonate = calcium sulphate + aluminum hydroxid + carbon dioxide

$$Al_2(SO_4)_3 + 3\,Na_2\,CO_3 + 3H_2O = 3\,Na_2(SO_4)_3 + 2\,Al_2(OH)_3 + 3\,CO_2$$

aluminum sulphate + sodium carbonate + water = sodium sulphate + aluminum hydroxide + carbon dioxide

The floc is formed by the insoluble aluminum hydroxide.

The complete reaction, when aluminum sulphate is used, requires theoretically 7.7 p.p.m. of alkalinity for each grain per gallon (17.1 p.p.m.) of alum; actually each grain per gallon of alum requires 6 to 10 p.p.m. of alkalinity with which to react, and there should be also an excess alkalinity of 20 to 25 p.p.m. in the filtered water in order to prevent corrosion.

For instance, assuming 8 p.p.m. of alkalinity is required for each grain per gallon of aluminum sulphate used, with a dosage of 1½ g.p.g., 8 x 1½ = 12 p.p.m. of alkalinity required for the reaction, with this amount of aluminum sulphate, plus 25 p.p.m. to prevent corrosion = 37 p.p.m. of alkalinity required. If this is not present, it must be added in the form of lime or soda ash.

If sufficient alkalinity is not present in the water, some of the aluminum sulphate will remain in solution. Soda ash or sodium carbonate (Na_2CO_3) can be used to furnish alkalinity; 0.5 grain of sodium carbonate combines with 1 grain of aluminum sulphate, and in doing so produces 3.4 p.p.m. of free CO_2; 0.5 grain of sodium carbonate will combine with 3.6 p.p.m. of CO_2. Therefore a dose of 1 g.p.g. of sodium carbonate reacts with 1 g.p.g. of aluminum sulphate, furnishing the required alkalinity and combining with the free CO_2 produced. Lime may also be used to furnish alkalinity: 1 g.p.g. of aluminum sulphate will combine with 0.35 g.p.g. of lime.

Aluminum sulphate reacts best at pH values of 6.5 to 8.5 (also around 5.5). A minimum dosage in clear water is about 0.3 g.p.g. Larger amounts are required for turbid waters, but there is no fixed rule to govern dosages. Experiments and experience with each water form the best guide. Large flakes of floc indicate a dose larger than is needed. In cold or very warm weather larger dosages may be needed.

Black Alum.—Black alum is a mixture of 4% by weight (16% by volume) of activated carbon with an aluminum sulphate having the formula $Al_2(SO_4)_3$, 9 H_2O, and containing 7% to 9% highly colloidal silicateous material. It is used for treating waters of low turbidity and subject to organic pollution from decaying vegetation. Dosages are the same as for aluminum sulphate previously described and the physical properties are essentially the same except that black alum is black. When feeding, a slightly higher velocity of dissolving water in the solution pots or in tanks under dry feed machines is needed; for delivery at some distance from feeders, a water ejector is desirable.

Ferrous Sulphate. — This chemical frequently called copperas, should not be confused with copper sulphate which is used for algae control. It has the formula $FeSO_4$, 7 H_2O. It is available in lump form, or as the granular sugar sulphate of iron, in which form it contains less than 7 molecules of water.

Lime must be added to the water. When it is added to the water before the ferrous sulphate is added, the reaction is:

$$Fe\,SO_4 + Ca(OH)_2 = Fe(OH)_2 + Ca\,So_4$$

ferrous sulphate + lime = ferrous hydroxide + calcium sulphate

When the ferrous sulphate is added to water containing alkaline carbonates, the reaction is:

$$Fe\,SO_4 + Ca\,(HCO_3)_2 =$$

ferrous sulphate + calcium bicarbonate =

$$Fe\,(HCO_3)_2 + C_a\,SO_4$$

ferrous bicarbonate + calcium sulphate

If lime is then added, the reaction is:

$$Fe\,(HCO_3)_2 + 2\,C_a\,(OH)_2 =$$

bicarbonate of iron + lime =

$$Fe(OH)_2 + 2\,CaCO_3 + 2\,H_2O$$

ferrous hydroxide + calcium carbonate + water

In either case the dissolved oxygen in the water oxidizes the ferrous hydroxide to ferric hydroxide, which is the desired coagulant, as follows:

$$4\,Fe(OH)_2 + 2\,H_2O + O_2 = 4\,Fe(OH)_3$$

ferrous hydroxide + water + oxygen = ferric hydroxide

When ferrous sulphate is used, dosages will be approximately the same as when alum is used. The lime dosage, with relatively clear waters, will be about 0.4 grain of lime per grain of ferrous sulphate, and the amount of lime required increases with the turbidity of the water, so that when the turbidity is considerable, as much lime will be required as ferrous sulphate.

For any water, enough lime is required to form the reaction with the ferrous sulphate used; to remove the CO_2 present in the water; and to provide an excess of not more than 4 or 5 p.p.m. About ½ p.p.m. of dissolved oxygen must be present in the water or provided otherwise for each grain per gallon of ferrous sulphate used. Where the oxygen is deficient, prechlorination may be employed to provide it.

Ferrous sulphate and lime may be advantageous where the water is hard and contains considerable turbidity. It is not suitable for the treatment of colored water, as soluble compounds may be formed in combination with organic matter, causing a dark color in the treated water, or fixing the color that exists.

Chlorinated Copperas.—Chlorinated copperas is made at the point of use by adding chlorine to a ferrous sulphate solution. The reaction between the chlorine and the copperas is:

$$6\,Fe\,So_4 + 3\,Cl_2 =$$

ferrous sulphate + chlorine =

$$2\,Fe_2(SO_4)_3 + 4\,Fe\,Cl_3$$

ferric sulphate + ferric chloride

Theoretically one pound of chlorine is required to react with 8 pounds of ferrous sulphate; in practice about 10% extra should be added to insure complete oxidation of all the copperas. When chlorine is added to act as a disinfectant, enough extra may be added to react with the copperas. The coagulating agent is the ferric hydroxide, obtained through reaction with the alkaline carbonates.

Chlorinated copperas is effective in removing color, as the hydroxide forming the floc is insoluble, even over a wide pH range. Coagulation and floc formation are usually best at a pH below 7.

Other iron salts that are occasionally used are ferric chloride and ferric sulphate. They have an especial value in the coagulation of waters containing considerable manganese, lime being used to raise the pH above 9.

Sodium Aluminate.—Because of its higher cost, sodium aluminate is not widely used in coagulation, but it has a special field in the treatment of boiler feed waters, especially when used with lime and soda ash. The sodium adds alkalinity and tends to soften hard water.

Lime.—Lime is available as calcium oxide, CaO or hydrated, $Ca(OH)_2$. The calcium oxide is the quicklime and must be slaked before use, and fed as a solution. Hydrated lime can be fed dry. When used in large quantities, as in a large plant, the quicklime is cheaper, but hydrated lime is handier for the small plant. It does not deteriorate when stored and is obtainable in handy-sized paper bags.

When using lime, the calcium content is important, and must be known in order to dose properly. Quicklime may vary from 75% to 99% CaO, and should be bought and used on the basis of its CaO content. Hydrated lime varies between 85% and 99% Ca (OH_2).

Assuming 100% CaO in the quicklime and 100% Ca $(OH)_2$ in the hydrated lime, 75.7 pounds of quicklime equals 100 pounds of hydrated lime; and 100 pounds of quicklime is equal to 132 pounds of hydrated lime.

These relationships must be modified by the contained percentage of CaO or Ca $(OH)_2$ in the lime used. For instance, if the hydrated lime contains 95% CaO $(OH)_2$, it will require $132 \div 95 = 140$ pounds to equal 100 pounds of 100% CaO.

Lime is used in coagulation to provide added or "artificial" alkalinity for reactions with aluminum sulphate and copperas, and also for softening, which will be discussed later. It may be used alone as a coagulant for waters containing a large amount of magnesium, by the precipitation of magnesium hydroxide by excess lime.

Soda Ash.—Soda ash is the common name for sodium carbonate, which has the formula Na_2CO_3. It is used, as already stated, to furnish artificial alkalinity for coagulation, and also for softening water. Most soda ash is 98% or more sodium carbonate.

When used in connection with aluminum sulphate to furnish alkalinity for coagulation, the reaction is:

$$\underset{\text{Aluminium sulphate}}{Al_2(SO_4)_3} + 3\ \underset{\text{sodium carbonate}}{Na_2CO_3} + 3\ \underset{\text{water}}{H_2O} =$$

$$2\ \underset{\text{aluminium hydroxide}}{Al_2(OH)_3} + 3\ \underset{\text{sodium sulphate}}{Na_2SO_4} + 3\ \underset{\text{carbon dioxide}}{CO_2}$$

An excess of sodium carbonate is usually added to combine with the CO_2. This produces sodium bicarbonate. Use of sodium carbonate does not increase hardness.

Though soda ash is more costly than lime, it has advantages for coagulation in the small plant. It is easy to feed, eliminates "after precipitation" and does not increase hardness.

Sulphuric Acid. — Sulphuric acid, H_2SO_4, is sometimes used in water purification principally to reduce the pH of certain colored water. Most colored waters coagulate best when slightly acid, and the lower pH may also reduce the amount of aluminum sulphate required for coagulation.

Applying Chemicals. — Thorough mixing of the chemicals with the water is necessary for the reaction to be complete. The water to be coagulated is often given preliminary sedimentation to remove as much as possible of the suspended matter. In modern plants, the water is dosed with the coagulating chemical, mixed vigorously for a few minutes, followed by a slower mixing (called "flocculation") for a longer period, and allowed to settle. Application of the chemical to the water may be dry feed machines or by solution feed.

Aluminum sulphate may be fed dry or as a solution. In either the large or the small plant, the use of ground aluminum sulphate is often preferable as it eliminates the trouble of making up solutions. Ferric chloride is fed as a solution; ferrous sulphate is ordinarily fed dry; also usually ferric sulphate.

A dry feeder consists of (1) a storage hopper, contracting to a throat at the bottom through which the chemical passes; (2) a feeding arrangement which is adjustable to give different rates of feed; and a mixer, as a solution pot, for making a solution of the chemical and the water. These units are furnished by several manufacturers, in a variety of types. Solution feeding equipment is of the piston displacement, or of the constant head orifice type, both of which forms are discussed at slightly greater length in the section on *Disinfection.*

How to Compute Dosages of Chemicals

There is no rule or formula for determining coagulant doses for best results. Acidity, alkalinity, the character and amount of turbidity, temperature, color and other factors influence the amount and even the type of chemical. Results obtained in another plant, even one treating water of a similar nature, can be used only as a rough guide. Laboratory tests are valuable indicators of the probable dosages that will be required. In the final analysis, experience gained by close observation and study and actual records of results at the plant in question are the best guide.

Procedure in Laboratory Tests.— In making these tests, a measured amount of the water to be coagulated is placed in beakers or jars, and dosed with different amounts of coagulant. The water and coagulant is then stirred until the floc forms, and this is allowed to settle, duplicating as closely as possible plant operations.

There are available several excellent kits for this work. These consist of 1, 2, 4 or 6 beakers, each holding about 1 liter, with electrically driven paddles for stirring the water to form the floc. Some of them have arrangements for varying the speeds of the paddles. Equipment with 4 or 6 jars is preferable. If such equipment is not available, one or two quart fruit jars may be used, and the stirring done by hand, with a glass rod or an eggbeater. It is best to mark each jar or beaker to indicate exactly one liter; or 1 quart, if this unit of measure is to be used.

Preparing the Solutions

Aluminum Sulphate.—While the use of grains per gallon is most common in coagulation, the use of parts per million seems preferable, especially since the two terms are easily converted. Add 10 grams of aluminum sulphate or "blackalum" to 1 liter of distilled water. One ml. of this solution, when added to 1 liter of the water to be treated is equal to a dose of 10 p.p.m. or about 0.6 g.p.g.

Soda Ash.—Soda ash is usually 98% strength. Using this as a basis, add 10.20 grams of soda ash to 1 liter of distilled water. One ml. of this solution when added to 1 liter of water is equal to a dose of 10 p.p.m.

Lime. — Using 1 liter of distilled water, add 10 grams of lime. One ml. of this solution, when added to 1 liter of water gives a dose of 10 p.p.m. This is on the basis of 100% C_aO which is seldom the case. If the C_aO content is known, vary accordingly. For instance, when using 88% hydrated lime, use $100 \div .88 = 1.17 \times 10 = 11.7$ grams to the distilled water, instead of 10 grams.

Dosages in Grains per Gallon.—To prepare a solution for dosages in grains per gallon, add 17.1 grams of the chemical to 1 liter of distilled water. One ml. of this solution when added to 1 liter of the water to be treated equals a dosage of 1 grain per gallon. Allowance must be made for the strength of the chemical. For aluminum sulphate, use 17.1 grams; for 98% soda ash use $17.1 \div .98 = 17.44$ grams; for 88% lime use $17.1 \div .88 = 19.65$ grams.

Testing Dosages of Alkaline Waters

Procedure.—To each of 6 jars (a lesser number may be used) containing 1 liter of the water to be treated, add different dosages of aluminum sulphate. Alkaline waters do not require the addition of lime or soda ash to furnish the alkalinity for the reaction with aluminum sulphate, if the alkalinity present in them is sufficient.

Assuming the test is being made with 6 jars and that the solution being used contains 10 grams of aluminum sulphate to 1 liter of water, the jars may be dosed as follows:

Jar. No.	*Dose in ml.*	*Equivalent Sulphate Dose in p.p.m.*	*in g.p.g.*
1	1	10	0.58
2	2	20	1.17
3	3	30	1.85
4	4	40	2.34
5	5	50	2.92
6	6	60	3.50

After stirring for about 15 minutes, allow the samples to stand and note the floc that forms. If none forms, the water is probable deficient in alkalinity or is so excessively turbid as to require even more aluminum sulphate. The smallest dosage of chemical that produces a good floc that settles well should be used. A large flaky floc indicates that the dose of chemical is unnecessarily large, and may be reduced somewhat. Note the pH of the jar showing the most satisfactory floc.

Water Deficient in Alkalinity

The factors involved in coagulation with aluminum sulphate have been mentioned. For each dosage of 1 grain per gallon of this chemical, 7.7 p.p.m. of alkalinity are needed, and there should be also an excess of 20 to 25 p.p.m. to prevent corrosion. Actually, this reaction does always take place with the theoretical quantities of alkalinity, being influenced somewhat by other factors.

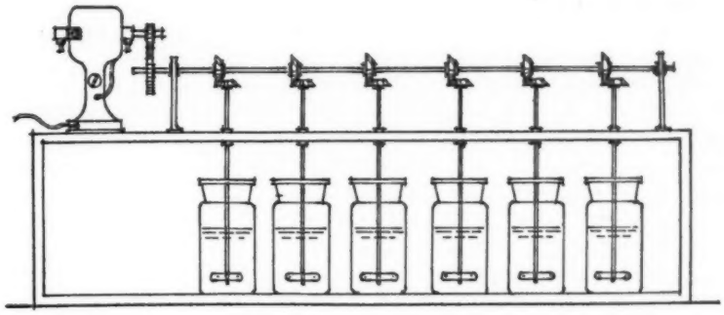
If the alkalinity of the water is known, the requirements for coagulation can be computed approximately, and the deficiency in excess of alkalinity thus determined.

Assuming that the natural alkalinity of the water to be treated is 22; that each grain per gallon of aluminum sulphate requires 8 p.p.m. of alkalinity (instead of the theoretical 7.7 p.p.m.); and that an excess alkalinity of 25 p.p.m. is desired, the amount of lime or soda ash that must be added for any dosage of aluminum sulphate is computed as follows:

Dose of Aluminum Sulphate	*Alkalinity Reaction*	*Need for Reserve*	*Total Alka.*	*Natural Alka.*	*To be Added*
1 g.p.g.	8	25	33	22	11 p.p.m.
1½ "	12	25	37	22	15 "
2 "	16	25	41	22	19 "
2½ "	20	25	45	22	23 "
3 "	24	25	49	22	27 "
3½ "	28	25	53	22	31 "

The same procedure is now followed as for the use of aluminum sulphate in alkaline waters, except that soda ash or lime solution, prepared as already described, is also added to each jar to give the dosage shown in the last column of the above table, that is, 1.1 ml. for jar No. 1; 1.5 ml. for jar No. 2, etc.

[Note that the above procedure should be varied with certain waters, as in Georgia (W. H. Weir), Florida (Prof. Black), Virginia (Richard Messer), and doubtless in other places. The operator should consult his State Board of Health for this special information.]



A handy stirrer for laboratory use. (Courtesy National Lime Ass'n and Charles P. Hoover)

Results given by such tests are valuable as a guide in finding what dosage is best on a plant scale. The dosage shown by the jar test as best, may not be the best one, in actual plant practice, but it will usually be close to it, and with some modifications will usually give excellent results. It is good practice to run frequent jar tests.

Example.—From the jar test, it is found that 1½ g.p.g. of aluminum sulphate and 15 p.p.m. of alkalinity give best results. The flow of water to be treated amounts to 720,000 g.p.d. How much chemical is needed.

Solution.—A dosage of 1½ g.p.g. equals $142 \times 1\frac{1}{2} = 213$ pounds per million gallons. The flow is .72 m.g.d. Thus the aluminum sulphate required is $.72 \times 213 = 153.4$ pounds per day. There must be added 15 p.p.m. of soda ash or its equivalent. The amount required is $15 \times 8\,1/3 \times .72 = 90$ pounds per day of 100% soda ash of lime. If soda ash is 98%, about 92 lbs. will be needed, and if lime is 88%, about 102 lbs.

Mixing the Chemical.—Best results are usually obtained when the coagulating chemical is quickly, thoroughly and completely mixed with the water. This is accomplished by high speed paddles or propellers, by air agitation, or by passing the water through a channel having baffles placed in it. These give turbulence to the water and accomplish satisfactory mixing; but the use of the mechanical devices, such as the Dorr "turbo-mix," or the Link-Belt aerator-mixer, usually results in a saving of chemical. Such equipment provides a brief period of very rapid mixing followed by a longer period of stirring which results in building up a better floc. In most cases the period of rapid mix should not exceed four minutes.

Corrosion and Its Prevention

The corrosiveness of a water depends upon its pH value, CO_2 content, the alkalinity and the mineral content. The best method of preventing corrosion is to adjust these elements so as to deposit a thin coating of calcium carbonate on the interior of the piping system. This must be kept thin or it will clog the pipes, water heaters, etc.

The CO_2 content is the important factor; an excess increases corrosiveness, but some is necessary to hold the alkaline salts, as calcium and magnesium bicarbonates, in solution and prevent deposits in excess of the amount desired.

The control of the CO_2 content is best accomplished by adding an alkali, as lime or soda ash thus increasing the alkalinity; lime is generally used because of its economy.

The first step in control of corrosion is to determine the CO_2 content and the alkalinity to methyl orange. These values can be plotted on the chart Fig A, which is based on a similar chart in Water Supply Control, by C. R. Cox and published by the New York State Department of Health, and which shows the relationship between alkalinity, CO_2 content and corrosiveness. For instance a water having an alkalinity of 100 p.p.m. and a CO_2 content of 5 p.p.m. would be only slightly cor-

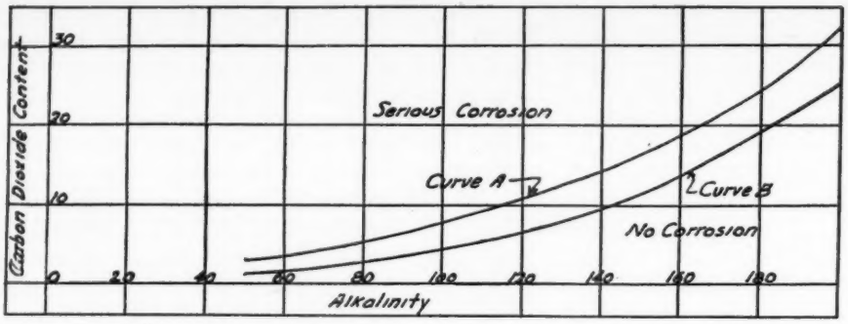


Fig. A. Relation between corrosion, alkalinity and Co_2

rosive; but if the alkalinity were only 50 p.p.m., and the CO_2 content 5 p.p.m., it would be seriously corrosive. Therefore, increasing the alkalinity reduces the corrosiveness.

The relationship between pH and alkalinity is shown in Fig. B, also adapted from Cox's Water Supply Control, which illustrates the effects of pH and alkalinity. On this are shown three curves: If the pH and alkalinity, when plotted, fall along the line C, the water may be mildly corrosive, but iron stains will be prevented. If pH and alkalinity fall along curve B, both corrosion and deposits on the piping will be prevented. If the values are along curve A, a protective coating of calcium carbonate will be built up on the pipes. If values shown on A are exceeded, excessive deposits may form; if values are below C, corrosion will take place.

Determining Amount of Lime or Soda Ash.—The simplest method of determining the amount of lime or soda ash necessary to prevent corrosion is by the *marble test.* Place a sample of the water in a beaker or a wide-mouthed bottle, and in the water place several pieces of pure calcium carbonate (also called calcite). The CO_2 present in the water dissolves the calcium carbonate to bicarbonate. This reaction continues until all the corrosive elements have been neutralized, during which time the pH value increases. Make pH tests from time to time; when pH no longer increases, but remains constant, the water is stable. It is then only necessary to add to the water to be treated sufficient lime or soda ash to raise the pH value to that finally shown on the marble test.

To compute the amount of lime, for instance, necessary, a jar test similar to that already described is simplest. To make a lime solution, add 10 grams of lime to 1 liter of distilled water; one ml. of this solution added to one liter of the water to be tested equals a dosage of 10 p.p.m., or 83 pounds per million gallons. It is not necessary to know the CaO content of the lime, as the dosage is computed directly in pounds per million gallons. Add the lime solution, testing for pH after each addition. When enough lime has been added to raise the pH to that determined by the marble test, the necessary lime dosage in pounds per million gallons equals 83 times the number of ml. of lime solution used.

When the alkalinity and CO_2 content are known, the needed amount of lime can be computed directly. One part per million of 100% CaO will react with 0.8 p.p.m. of CO_2; on the basis of 88% CaO content, 1 p.p.m. of lime will react with 0.7 p.p.m. of CO_2. Requirements of a water having a CO_2 content of 10 p.p.m., a methyl orange alkalinity of 90 p.p.m., and no phenolphthalein alkalinity, would be computed as follows:

The free CO_2 is 10 p.p.m.; the half-bound CO_2 is 44% of the alkalinity, or 39.6 p.p.m.; the total CO_2 to be neutralized is $10 + (90 \times 44) = 49.6$ p.p.m. There will be required (using 88% CaO lime), $49.6 \div 0.7 = 71$ p.p.m. or $71 \times 8.3 = 589$ pounds per million gallons.

Filters and Their Operation

A filter is primarily a bed of sand through which the water passes. During the passage of the water through the sand practically all of the suspended solids, some of the dissolved solids and most of the bacteria are removed. This action is due in part to the straining action of the sand, and in part to a jelly-like formation which coats the grains of sand and entraps the fine particles of material and also the bacteria, as these are carried through by the water.

In order that the sand bed may work most effectively, it must be so constructed that water can be applied to the surface of the bed and collected at the bottom. In practice this means that the filter is placed in a concrete or steel tank; that underdrains and a collecting system are built beneath it to collect the filtered water; and that valves and controls are needed to regulate the passage of the water to and through the filter. The water must flow to and through the filter at a regular and proper rate.

The general structure of a filter is shown in the accompanying illustration.

Sand for Filters.—For filter purposes, quartz sand or silicates (sometimes also anthracite coal), which are not affected by characteristics of the water, should be used. Ordinary bank sand cannot be used without screening, washing and grading to produce the correct size, and unless it is free from lime and magnesium carbonates.

If the sand is too fine, it will offer excessive resistance to the passage of the water and will require frequent cleaning; if too coarse, it may remove too little of the material that it is desired to take out. From experience over a long period of years, the sizes of sand that give best results have been determined. The two factors, aside from those of the composition of the sand are known as "effective size" and "uniformity coefficient."

Effective Size of Sand.—The *effective size* of a sand is that size such that 10% of the sand grains by weight are smaller than it. This factor is simply a means of describing the fineness of a sand in terms that can be used with precision and exactness in water works practice. When described by this term, a fine sand would be one having an effective size of 0.17 or 0.18 millimeters; and a coarse sand would be one having an effective size of 0.45 or 0.50 m.m.

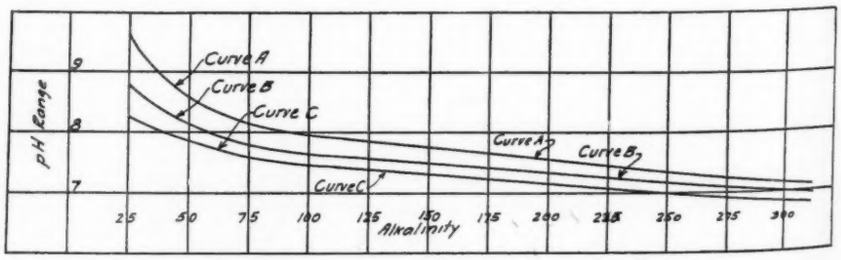


Fig. B. Relations between pH, alkalinity and corrosion

Uniformity of Sand.—The uniformity of a sand is another characteristic of importance in water purification. The *uniformity coefficient* is the ratio between the effective size and that size such that 60% of the sand is finer than it. Both uniformity and effective size are necessary to describe a sand.

Slow Sand Filters

The Sand Layer.—The sand layer is ordinarily 30 to 40 inches deep; beds of fine sand may be shallower than those of coarse sand. The critical depth is that which will provide the required degree of purification, and will also allow several scrapings or cleanings without reducing the depth of the bed below that which will prove effective. The loss of head is greater with fine sands, and they require more frequent cleanings.

The effective size of sand should range between 0.2 and 0.3 m.m., and the uniformity coefficient should be between 2.0 and 3.0

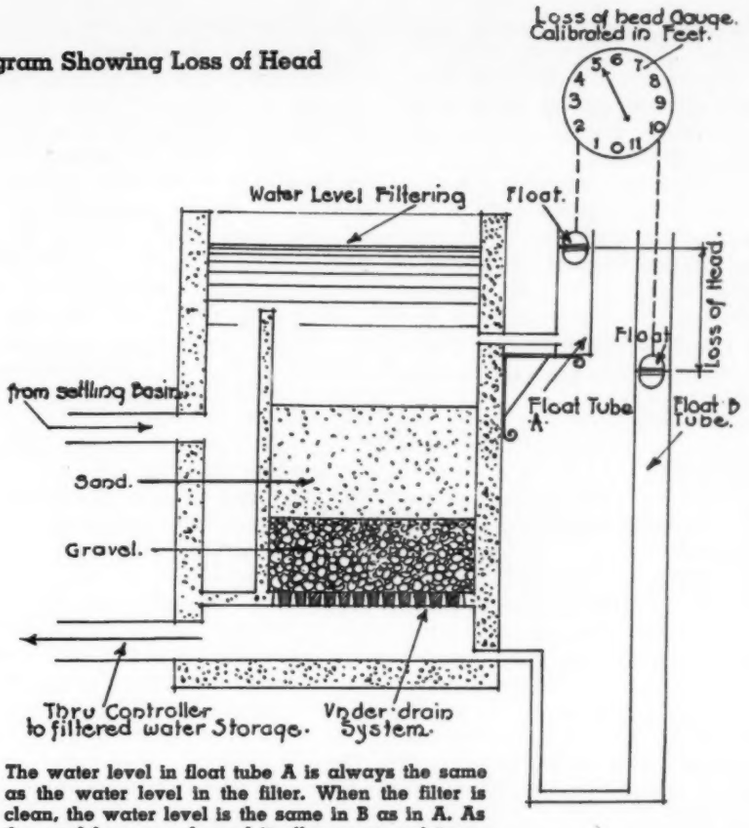
Underneath the sand bed is the gravel layer which surrounds and covers the underdrains. This is 12 to 15 or 18 inches in depth, with coarser stone 1-inch to 3-inch size, at the bottom, and with graded layers of finer stone supporting the sand bed. The underdrain system is of tile, as a rule, built on or in the floor. Floors and walls should be tight and generally are of masonry. Beds vary in size, and may be from ¼ to 1 acre, or larger or smaller. In northern areas, filters are usually covered; operation is difficult when ice forms.

The depth of water normally maintained on the filters is 3 to 4 feet, though in some plants it is greater. This depth is maintained by means of rate-of-flow controllers which regulate the inflow of water to the bed and control the rate of discharge.

The control of the rate of operation is practically the only factor available to the operator of a slow sand filter. The character of the raw water and the period of sedimentation (unless there is excessive capacity in the sedimentation basins) are beyond his control. The maintenance of a proper rate—usually 4 million to 6 million gallons per acre per day—remains the only means of control of the quality of the water, aside from filtration.

Loss of head is the resistance offered by the sand to the passage of water through it. This is slight at first, but increases as the sand is clogged with material that is strained from the water. When the loss of head reaches several feet, the beds should be cleaned. There is no standard loss of head at which cleaning is considered necessary; it varies from 2 to 6 feet, usually being about 4 or 5 feet. Cleaning may be necessary, depending on the condition of the water at intervals of 2 to 10 weeks.

Diagram Showing Loss of Head



The water level in float tube A is always the same as the water level in the filter. When the filter is clean, the water level is the same in B as in A. As the sand becomes clogged it offers more resistance to water going through it and the pressure in the underdrains becomes less, causing water in float tube B to drop. The gauge records difference in feet, When the water in tube B drops below the underdrain, the filter is operating under negative loss of head. (Courtesy Nat'l Lime Ass'n and C. P. Hoover)

The total head on the filter, neglecting any friction of the sand, is as follows: Water on the filter 3 to 4 ft.; depth of sand and gravel 4 to 5 ft.; total 7 to 9 ft. In addition, if suction be permitted on the discharge pipe additional "negative head" will be available. Employment of negative head is poor practice at it may result in cracks or breaks in the bed, and also in unsatisfactory treatment of the water.

Cleaning the Sand.—When the loss of head is such that the beds must be cleaned—this varies in different plants but is usually about 4 feet—the water is drained down below the sand level so that men equipped with foot pads can walk on the surface. Using flat shovels, the surface sand is scraped off to a depth of ¼ to 1 inch. Removal of the sand may be by an ejector, a conveyor or by wheelbarrows operating on planks.

Sand washers are available for cleaning the sand so it can be used again. These generally use a jet of water and violent agitation for washing.

Cleaning by removal of a thin sand layer is continued until the depth of remaining sand is not less than 24 inches, when 6 to 12 inches of clean sand are added, bringing the beds to the original depth.

Placing a Cleaned Filter in Operation.—The following procedure should be followed in placing slow sand filters in operation after cleaning: Filtered water from other beds or from the mains should be turned slowly into the underdrains of the cleaned bed until the water rises several inches above the sand surface, Raw water can then be turned in but the rate should be such that the sand will not be scoured. Filtration can then be started at a very low rate, gradually increasing over a period of several days—four days when the filter has been scraped to a week after replacement of sand. During this period, and until tests show the quality of the water to be satisfactory, the effluent from this filter should be wasted.

Mechanical or Rapid Sand Filters

A rapid sand filter consists of a bed of sand about 24 or 30 inches deep which is supported on a layer of graded gravel 12 to 18 inches deep. The sand usually used in a filter of this type should have an effective size of 0.35 to 0.50 m.m., and a uniformity coefficient of 2.0 or less; that is, the sand should be quite uniform in size. The gravel ranges from 2-inch or 3-inch pieces at the bottom to coarse sand at the top.

While the rapid sand filter resembles

the slow sand filter in having sand bed, gravel layer and underdrains, it differs in a number of particulars. Most important of these are the filter cleaning or washing devices and the appurtenances thereto.

The rapid sand filter operates at a rate of about 125,000,000 gallons per acre per day, or 2 gallons per square foot per minute. Because of this rapid rate, and the great volume of water filtered—some 30 times as much per square foot as the slow filter—special provisions for frequent and rapid washing are necessary.

This is accomplished by reversing the flow of water through the filter, and by passing it upward through the sand at a rapid rate. This washes out the dirt; the dirty water flows off into gutters and is wasted.

Before filtration, the water is always conditioned by coagulation and settling, as previously described. This also is important in insuring good filtration and a clear water. Particles of the floc which do not settle out collect on the surface of the sand and form a mat which greatly aids in straining all the suspended matter and most of the bacteria from the water.

Size and Arrangement.—Rapid sand filters are most often constructed as rectangular units, side by side, in two rows, between which is a passageway containing operating and control units. The necessary piping is frequently placed under this passageway or operating floor, and the clear water basins under or outside of the filter units.

A filter unit 18 ft. by 20 ft. will handle about 1 m.g.d. Units vary from ½ m.g.d., or even less, to 2 m.g.d. in the larger plants. In very small plants, the units are frequently circular.

Loss of Head.—The gravel bed depth (12 inches or more), plus the depth of sand bed (usually 30 inches), plus the height of the wash water troughs above the sand (usually 24 inches), plus the freeboard above the troughs (usually some 4 feet) make up the depth of the filter. On the above basis, the depth would be 9 feet 6 inches, which would be the head available without employing negative head.

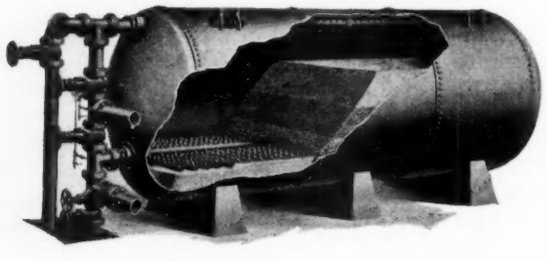
When the filter is first put in operation after washing, the loss of head due to friction in passing through the sand is small—often about a foot. As the filter becomes dirty, this increases; when it becomes as much as 7 to 9 feet, the filter must be washed.

This variation in loss of head requires the use of rate controllers so that a uniform rate of filtration is maintained at all times. The maintenance of a uniform rate of filtration is very important. A sudden increase in the rate of flow may cause breaks in the bed; and a rapid decrease may release air held in the water, causing air-binding.

Rate Controllers.—A rate controller is designed to regulate automatically the flow through the filter so as to maintain a uniform rate of discharge regardless of the change of loss of head in the sand, or of the change of elevations of the water in the filter and in the clear water basin. It does this by consuming or wasting pressure or head. It continually adjusts its valve openings as necessary so that the predetermined or "set" rate shall pass through them from the start of the filter run until the valves are wide open. It is a mechanical hand which controls the valve during the entire run of the filter.

The rate controller is a vital part of the filter plant, since it maintains these conditions essential for effective filtration. It may do this by regulating the flow through the sand bed while it is operating with an excess head; or it may operate as a safety device to limit the maximum rate through the filter when it is desired to keep the clear well level as near as possible to the filter level. All rate controllers consist essentially of a venturi tube which measures the flow of water and operates a diaphragm actuator to regulate the valve opening. The manufacturers of this equipment will supply descriptive information on request.

Umbrella nozzle (International)



Phantom view of Pressure Filter; a gravity filter is essentially the same as regards underdrains, gravel and sand.

Strainers: at left, cast iron "umbrella"; center, brass strainer; right, stainless steel (Permutit)

Checking Rate of Flow Through Filters. — Operators can calculate the rate of flow through the filter, thereby checking the rate controller, as follows: Fill the filter with water; shut off the influent line; determine the time necessary to filter down one foot. For example, if it requires 4 minutes for the water to drop one foot, the rate of filtration is $7.48 \div 4 = 1.87$ gals per square foot per min. This multiplied by the filter area will give the rate in gallons per minute for the entire filter unit; and this result multiplied by 1440 will give gallons per day.

Washing the Filter.—When the loss of head in the filter has reached the point where washing is necessary, the influent valve is closed, and the water is drawn down below the tops of the wash water troughs, the filtered water outlet being closed. Water is then admitted slowly to the underdrain system, and then more rapidly until the usual washing rate is attained.

On most plants this rate is 15 gallons per square foot per minute, or 7½ times as fast as the filter rate. Also since there are 7½ gallons in a cubic foot, the rate is 2 cu. ft. of water per square foot and the "rise" or upward velocity of the water is 24 inches per minute. On some of the newer plants, higher rates are used (as high as 36 g.p.m. per square foot).

The upward flow of water "floats" the sand, expanding it by 40% to 50% of its volume, and washes out the dirt; the dirty water overflows into the wash troughs and out through the waste drain. Washing should continue until there are large clear areas in the wash water as it rises through the filter. Washing will ordinarily take 7 to 10 minutes. When it is completed, the wash water valve is closed; the waste or sewer valve is closed, and the influent valve is opened sufficiently to bring the water in the filter to its normal level. The water is then allowed to filter to waste for at least 3 to 5 minutes in order to build up a mat on the surface of the sand sufficient to produce a clear effluent. Bacterial removal is not very good immediately after washing.

Air Wash.—Some filters have small pipes between the sand and gravel layers, which pipes are for the purpose of carrying air under pressure to

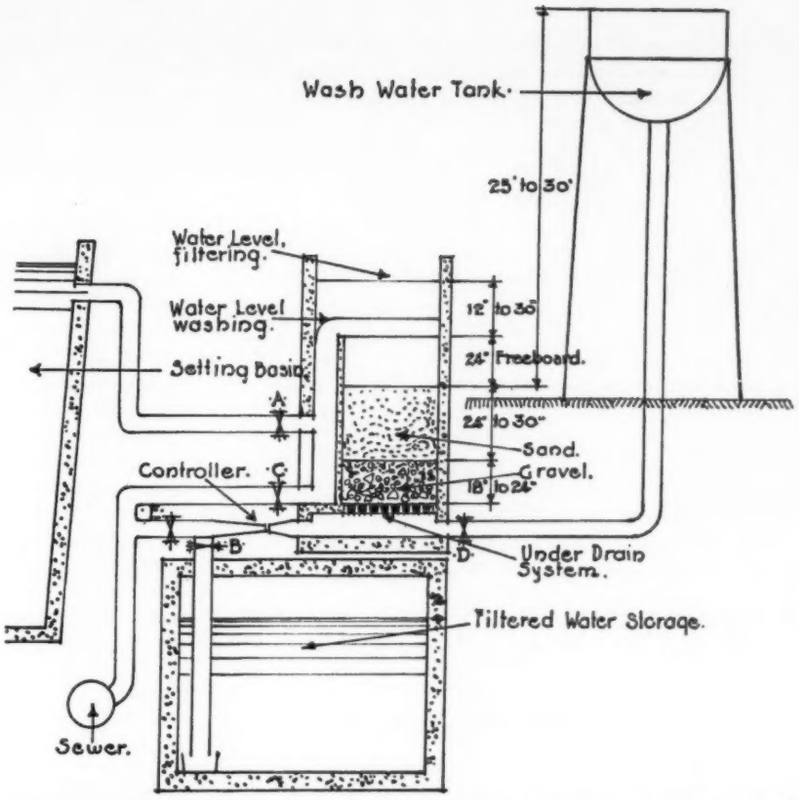
agitate the sand. This air is furnished from a compressed air tank or from a compressor unit. In washing, the influent valve is closed and water drawn down nearly to the surface of the sand. The air is then applied at the rate of 2 to 5 cu. ft. of air per square foot of filter per minute for 3 or 4 minutes. After the agitation and stirring has been accomplished, the air valve is closed, filtered water turned into the underdrains, and washing carried on as before described. Less wash water is used—as a rule from 6 to 10 gallons per square foot.

Some of the older filters have revolving stirrers or rakes. In washing, these are started slowly, wash water being turned on at the same time. Washing and stirring continue until there are large clear areas in the rising wash water. The rake or agitator is then reversed, and raised above the bed. The wash water valve is then closed, and the sewer valve closed. The filter is then put into service but allowed to filter to waste until a mat has been formed on the sand.

Determining the Rate of Wash.—A simple method of determining the rate of wash is recommended by Charles P. Hoover, as follows: Draw down the water to the top of the wash water trough; shut the wash water outlet valve; determine time for wash water to rise two feet. For example, if the wash water rises 2 feet in exactly one minute, the rate of wash will be $2 \times 7.48 = 14.96$ gallons per square foot per minute.

Measuring Sand Expansion. — The upward velocity of wash water should be sufficient to expand the sand from 40% to 50%; that is, with a sand bed 24 inches deep, the depth during washing should be 33 to 36 inches. During the summer, there may be less sand expansion; even not enough to insure proper washing at the 15 g.p.m. rate. This is probably due to the higher temperature and less viscosity of the wash water, and it may be necessary to increase the wash water rate.

To measure the expansion of the sand, a sand expansion indicator is available from Simplex Valve and Meter. Cox (in Water Supply Control, N. Y. State Department of Health) suggests fastening of small metal cups (about 1 inch in diameter and ¼ inch deep) to a 24" rod at intervals of 2 inches, the upper cup being 6 inches from the top of the rod. The rod is fastened to the wash water trough so that the topmost cup is 6 inches below the lip of the trough. When the bed is washed, any deposit in the cups will mark the height to which sand has been carried by the wash water. For instance, if the cup 12 inches above the normal level of the sand bed contains sand, but the cup 14 inches above the bed does not, the expansion will be at least 12 inches, or 50% of the sand with a 24 inch bed.



How Filter Operates: 1. Open valve A. This allows water from settling basin to flow to filter. 2. Open valve B. This allows water to flow through filter. During filter operation all other valves are closed. How Filter Is Washed: 1. Close valve A. 2. Close valve B when water in filter filters down to top of overflow. 3. Open valves C and D. This allows water from wash water tank to flow up through the gravel and sand, washing the dirt out of the filter and into the sewer. How to Filter to Waste: 1. Open valves A and E. All other valves closed.

(Courtesy Nat'l Lime Ass'n and Charles P. Hoover)

Samples from the wash water trough, if placed in bottles and allowed to settle, will show if sand is being lost in washing. The loss of the finest sand from a new filter may be expected at first and is not objectionable.

Mud Balls. — Mud balls sometimes form in or on the sand. These generally indicate that the velocity of the wash water is too low or the time of washing too short. These may be removed by scraping the sand with shovels; or sometimes during washing by skimming them off with a long handled basket of ¼ inch wire mesh. On relatively small beds, the sand may be raked during the washing process by long-handled rakes, which break up the balls.

The presence of mud evenly distributed over the bed after washing, or accumulations of it near the wash water troughs indicate that wash water velocity is too low, washing time too short, troughs too high, or troughs too far apart. Cracks in the sand are usually due to mud being carried into the sand because of insufficient washing; but occasionally from the presence of clay or other cementing material which binds the sand grains together. A hand rake may be used to break up such areas.

Occasionally, after washing a filter the water should be drawn down below the surface of sand to permit inspection and examination.

Removing Organic Matter.—Shrinkage of sand beds is sometimes due to the cementation of the sand grains by organic matter or gelatinous floc; also at times by fine clay, oil or microorganisms. Most of these can be remedied by treatment with alkali. A 2% or 3% solution by weight of caustic soda, sufficient in volume to cover the sand to a depth of 3 or 4 inches, and allowed to stand 12 to 24 hours will usually give satisfactory results. The outlets of the filter unit should, of course be closed before the caustic soda is added; after the alkali is drained off, the bed must be washed thoroughly.

Chlorine also is used, generally in the form of HTH or Perchloron, but also as chloride of lime and liquid chlorine. It is especially effective for destroying algae or slime-producing organisms. A very strong solution is prepared, and after the water has been drawn down to about a foot above the top of the sand, this water is dosed to give a strength of about 3,000 p.p.m.

The treated water is then lowered to about an inch above the sand level, thus drawing the chlorinated water into the interstices of the sand; after about 24 hours of contact, the bed is washed thoroughly.

Removing Sand. — Removal of the sand and gravel from the bed is a major operation, and is rarely necessary. Broken or clogged strainers occurring in sufficient number may make sand removal necessary for repair and replacement, but as long as satisfactory bacterial removal and turbidity reduction are obtained the presence of a few defective strainers is not important.

General.—In some plants that are operated only a part of the day, the filter is washed at the end of each day's run; and, of course, filters are washed whenever the loss of head or decrease in efficiency indicates. There is no set rule for this; approximate suggestions have been made for average loss of head conditions. As a matter of fact, all the filters in a given plant may vary somewhat; and there will also be variations from month to month, or even oftener.

There is no substitute for intelligent observation, the keeping of proper records, and a thorough knowledge of conditions at the plant. These form the best basis for good operation. Also there is a large amount of written and recorded experience covering the operation of many plants. The study of this material will reward any operator.

Good results are obtained by careful control of the two principal elements in the filtration process—the preparation of the water by conditioning, coagulation and settling, and the maintenance and proper operation of the filter bed. The proper controls, gauges and operating mechanisms are essential in all but the very smallest and simplest plants.

Disinfection of Water

None of the steps in water purification—storage, sedimentation, coagulation and filtration—nor all of them combined can be relied on to remove all of the bacteria from the water, though ordinarily only 1% or less survive these processes in a well operated plant. These are removed by disinfection.

Sterilization means that all life is killed; disinfection that all potentially dangerous organisms are killed. Because chlorine and its compounds are almost universally used for this purpose, the term chlorination is generally used in waterworks practice.

Chlorination is the final safeguard of the quality of the water. As such the necessity for its continuous and regular application in sufficient amounts to accomplish bacterial removal cannot be overemphazised. To do this requires good equipment; attention, care and intelligence; and the employment of proper tests and checks.

Chlorine is employed primarily in the form of liquid chlorine, Cl.; and also, especially in the smaller plants, as calcium hypochlorite.

Liquid chlorine is 100% available chlorine. Actually it is a gas, but under pressure it becomes a liquid in which form it is shipped in steel cylinders. The pressure varies with the temperature from 40 to about 150 pounds, being greatest at high temperatures. At 70° F, it is about 85 pounds per sq. in. The cylinders most used in waterworks plants contain 100 or 150 pounds of chlorine, but larger and smaller containers are available.

Liquid chlorine is the almost universal agent for disinfection, except in very small plants, where other methods are also used.

Calcium hypochlorite solutions are prepared from commercial bleach, also called bleaching powder, chloride of lime and chlorinated lime which is made by saturating quicklime with chlorine. Two types of calcium hypochlorite are available: The standard bleaching powder contains 25% to 35% of available chlorine and loses strength (that is, available chlorine) quite quickly when exposed to air. When stored in tight containers the chlorine content is lost more slowly, the rate of loss being around 1% a month. The other form available is more a stable form with a much greater chlorine content. HTH, or High Test Hypo. is made by Mathieson Alkali Co.; Perchloron by Pennsylvania Salt Co. These contain about 70% available chlorine.

Application of Chlorine to Water.— Too much chlorine in water causes tastes and odors; too little will not insure a safe supply. In small plants an attendant may not be on the job regularly, so that some means for insuring continuous automatic operation must be provided.

The requirements for equipment for applying chlorine to water are accuracy, within close limits, but most of all reliability for if the application of chlorine fails, an unsafe water and sickness may result.

Liquid Chlorine

Liquid chlorine is applied to water by means of a machine called a chlorinator. The function of the chlorinator is to take the liquid chlorine from the cylinder, measure it, and feed it in predetermined amounts into the water. Application may be in either of two ways, directly to the medium being treated, as a gas—or first mixed with water and the resulting solution applied. These two methods are known respectively as "direct feed" and "solution feed."

Direct Feed Application. — In a direct feed apparatus, the gas is taken from the cylinder through an auxiliary tank valve attached to the main tank valve and conveyed through chlorine resistant tubing to the chlorinator. It next passes through a pressure regulating valve, which compensates for varying tank pressures and delivers the gas to the metering device under a constant pressure. The flow of gas is usually measured by the pressure drop through an orifice or by some type of volumetric meter. From the meter the gas passes through tubing to a check valve, the function of which is to maintain a constant back pressure on the meter and to prevent water from entering the chlorine line when the apparatus is shut down. The gas is applied through some type or diffusor, usually a carborundum stone, which divides the gas into very small bubbles, making it easily absorbed by the water.

The principal difficulty with a direct feed apparatus comes from the plugging of the diffusor by chlorine hydrate or impurities; diffusion is seriously impaired, the chlorine gas passes into the water in large bubbles, is not absorbed quickly, and may attack the interior of the piping, valves and fittings, particularly at any high spots in the line. Entrained air in the water can also produce this result. A second difficulty with direct feed is due to the necessity for a chlorine gas check valve; this piece of equipment is hard to build to give continued positive action.

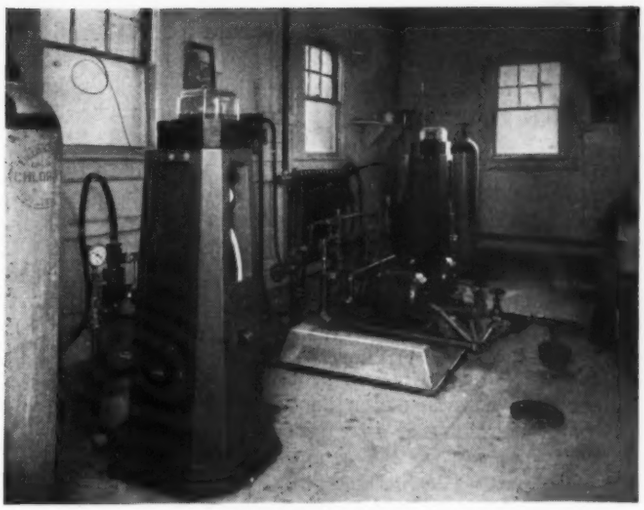
Solution Feed Application.—In this type of equipment the gas is drawn from the cylinder in the same way, and then dissolved in a small flow of water, the pressure of this water operating an injector which serves to apply the chlorine solution against pressure in the pipe line. This method of application does away with the difficulties experienced from poor diffusion and corrosion and eliminates the necessity for a gas check valve.

Typical Solution Feed Equipment.— While solution feed equipment may vary considerably in design, the path of the chlorine through a typical apparatus may be outlined as follows: 1) From the cylinder through the main and auxiliary tank valves and connecting chlorine resistant tubing to the

pressure regulating or reducing device on the chlorinator. A pressure gauge is usually placed in this line giving the pressure of the gas being drawn from the container in pounds per square inch. Tank pressures will vary from 125 pounds to 150 pounds in hot weather, dropping to 35 pounds to 45 pounds in cold weather. 2) The metering device is most often of the orifice type, though volumetric meters are also used on the small capacity types of apparatus. An orifice meter measures the flow of gas by measuring the pressure drop across the orifice or difference in pressure on its inlet and discharge sides. Since the flow is directly proportional to this differential pressure, orifices may be calibrated and built to give any desired flow of gas. The volumetric types of meters simply measure a certain volume of gas under a constant pressure, the number of times this fixed volume is filled and emptied per minute determining the amount of chlorine being applied. Volumetric meters are seldom used for chlorine application greater than 10 pounds per 24 hours. 3) The gas may be partially dissolved in water at the meter or carried to the injector throat still as a gas. The flow of water through the injector creates a vacuum just past the injector throat, this vacuum drawing in the chlorine gas or solution so that it is further mixed with the injector water and carried to the point of application. In making application against pressure in the pipe lines, various factors such as the type of apparatus being used, the length of hose run from chlorinator to main connection, the height of application point in relation to chlorinator, the amount of chlorine being applied, etc., all enter in fixing the water pressure necessary to operate the injector. A practical minimum ratio is at least 4 to 1, or an increase of 4 pounds in water pressure to the injector for every pound increase in back pressure.

Operation of a Chlorinator. — For proper operation, the room in which the chlorinator is kept should be over 50° F. Warm gas entering a colder chlorinator will condense and may cause clogging. Therefore, the chlorinator should not be placed on an outside wall, but should be in a warmer place than the cylinder or the pipe connecting the cylinder and the chlorinator. A radiator, a small stove, or an electric heater may be used. The chlorinator building should be insulated or well protected. When cold is not too intense, an electric light left burning, or a lighted lantern may furnish the required heat.

Chlorine cylinders should be kept on scales and the weight read each day as a check against the amount of chlorine used; or in the case of very small plants, the scales should be read every week.



A typical liquid chlorine installation with duplicate chlorinators (Wallace & Tiernan)

The maximum drawoff or discharge from 100 and 150 pound cylinders at 70° F is approximately 35 pounds per 24 hours. Due to the change from a liquid to a gas, an excessive drop in temperature will occur and if more than 35 pounds are used daily, 2 or more cylinders should be attached.

An ample reserve supply of chlorine should be kept on hand; also a reserve supply of duplicate parts, including valves, gaskets, etc. But the operator should not attempt major repairs. Whenever possible an entire duplicate chlorinator should be kept on hand for possible emergencies. Ask the manufacturer of your chlorinator for full directions for starting and stopping, and for other details regarding it.

Chlorine leaks are, of course, dangerous since the gas is irritant to the lungs and causes violent coughing. A concentration of 1 part of chlorine in 100,000 can be noticed; 1 part to 50,000 parts of air causes inconvenience; and 1 part in 1000 of air after 5 minutes exposure produces death. Leaks can be located by means of an open bottle of ammonia. Valves, connections and other places that may permit chlorine to escape are tested with the ammonia bottle. White fumes of ammonium chloride are formed when chlorine combines with ammonia. Gas masks are desirable to have on hand for use in case of leaks. Chlorine being heavier than air, ventilation at or near the floor level is desirable.

Metal parts on the chlorinator, or other metal surfaces, become corroded when a gas is present. To prevent this, these may be painted with a thin coating of gasoline and vaseline. The gasoline evaporates and leaves a light coating of vaseline which is sufficient protection.

Dosage of Chlorine.—The dosage of chlorine required for making water safe depends on many factors. Waters that are turbid, or contain much organic matter, iron or manganese, may require large amounts. Filtered water, or clear surface water of good quality requires a dosage of 0.2 p.p.m. to 5 p.p.m. The chlorine residual test already described is the essential guide to the amount of chlorine required. Most waters are effectively treated when there is 0.1 p.p.m. to 0.2 p.p.m. of residual chlorine present 10 minutes after the chlorine has been applied.

Chlorination With Calcium Hypochlorite

The bleaching powder is mixed with water, and settled; the resulting solution containing the chlorine is then fed into the water to be chlorinated by means of a solution feed machine. Effective treatment cannot be obtained by feeding the dry bleach.

It is easier to feed a weak solution using larger quantities, than to apply small amounts of a concentrated solution. For example, to make a solution containing ½% of available chlorine, using 100 gallons of water, which weighs 83 pounds: Chlorine required is ½% of 834 = 4.17 pounds. If the bleach has a chlorine content of 25%, which is about the average, $4.17 \times 4 =$ 16.68 pounds of bleach will be needed for 100 gallons of solution.

When HTH or Perchloron are used, with a 70% available chlorine strength, $4.17 \div 0.7 = 6$ pounds of chemical will be needed per 100 gallons of water.

Hypochlorite solution may be purchased ready for use; but it is usually cheaper to make it up. To do this, a mixing tank, with motor driven paddles is desirable. The bleach is added to the water, or preferably made into a paste and added. After mixing 15 to 30 minutes, the solution should be allowed to stand for an hour to permit the particles of lime to settle.

Solutions lose strength on standing

even in dark, cool places, and should therefore be used promptly.

Hypochlorite Feeding Equipment.—Feeding equipment for hypochlorite solutions are available in a variety of forms. One type feeds by means of a small diaphragm pump which draws hypochlorite solution from a suitable container and discharges directly into a pipe line against pressure. This type of equipment may be actuated either by electric motor or water motor and may be either manually or automatically controlled so as to obtain proportional feed, as by a water meter placed on the line. Other types of hypochlorite feeders operate on the constant level principle, variation of feed being accomplished by changing the height of an orifice in relation to the solution level; while still others are controlled by means of a clockwork mechanism which lowers a displacement cylinder into a solution reservoir at a predetermined rate. To attempt description of each of the various types here would involve much detail and would also be unnecessary since the principle of operation can be easily understood after a brief examination of the equipment.

Computing Dosages.—To chlorinate 100,000 gallons of water per day with a dosage of 0.4 p.p.m. of chlorine, the required amount of bleach is computed as follows:

100,000 gallons weighs 834,000 pounds or .834 million pounds; chlorine required is $.4 \times .834 = .33$ pounds of chlorine. If the bleach has a strength or 25%, there will be required $.33 \div .25 = 1.32$ pounds of bleach. If a ½% solution is to be used, the 1.32 pounds of bleach will be mixed with 264 pounds or about 32 gallons of water.

Disinfecting Mains and Reservoirs

Water mains should be protected against contamination while they are being installed; dirt and other material should be removed before laying. Before being placed in service, every section of pipe should be flushed out and then chlorinated, using a dose sufficient to give 40 to 50 p.p.m. of residual chlorine. In some places, the flushing out is omitted, and a small amount of bleaching powder, HTH or Perchloron is placed at the time of laying in each pipe, or in the case of small pipe, in each third or fourth length.

When using bleaching powder, 25% available chlorine, the following amounts are required for each 100 feet of pipe:

4-inch, 1½ ounces; 6-inch, 3½ ounces; 8-inch, 6 ounces; 10-inch, 10 ounces; 12-inch, 15 ounces; 16-inch, 36 ounces. When using HTH or Perchloron, 40% as much is sufficient; AWWA Standards suggest 1 pound (70% available chlorine) for each 1680 gallons of pipe capacity to be treated.

When the bleach is placed in the pipes as they are laid, the line is filled slowly with the water and allowed to stand for 3 to 12 hours; it is then flushed thoroughly. When the chlorine is not placed in the pipes, it should be made into a solution, and added to the line as it is being filled with water.

When liquid chlorine is used, a corporation cock is inserted in the old line near the point of connection with the new line, and a special stuffing box is inserted and connected to a chlorine cylinder with a silver or copper tube. The stuffing box and tube can be obtained from manufacturers of chlorinators; also special chlorinators for this purpose are available, and are preferable.

After the connection is made, the new line is flushed out; after it has drained, water is then turned into it slowly, and chlorine gas from the cylinder is turned into the main. Water pressure must be below 30 pounds or the chlorine may not flow.

Orthotolidine tests are made on the water as it comes out of the valve or hydrant at the far end of the line. When a strong red color is obtained by the test, allow the line to fill, shut off the chlorine, and the valve admitting water to the new line. Allow to stand for 3 to 12 hours, and flush thoroughly. If there is no valve or hydrant at the lower end of the line, a testing plug fitted with a stop-cock can be placed in the end of the pipe line, to permit the discharge of air as the line is filled with water, and also to permit taking samples of water for orthotolidine tests.

Elevated tanks, concrete or steel reservoirs, and other similar structures, should also be treated before being placed in service. Liquid chlorine may be added to the water as these are being filled; ½ to 1 pound of bleaching powder, 25% available chlorine, may be used for 1000 gallons of water.

Ammonia—Chlorine

When water contains certain industrial wastes, as phenol compounds, the addition of chlorine causes a disagreeable taste; the same trouble may occur if algae are present in considerable quantity in the water.

If ammonia is added to the water just before the chlorine is added, the reaction between the chlorine and the taste-producing organisms is prevented, and much or all of the taste problem is eliminated. The use of ammonia also permits the use of larger doses of chlorine without causing chlorine tastes.

Ammonia should be applied ahead of the chlorine so as to produce a thorough mixing of the ammonia with the water, but not so far ahead that the ammonia is reduced before the chlorine is applied. Generally a few feet is satisfactory.

When ammonia and chlorine are used, the two chemicals combine to form chloramines which do not react as quickly with organic matter as does chlorine alone. Consequently, the rate of disinfection is slower, and a longer period of contact—about 2 hours—is required. Water treated with ammonia and chlorine should not be used, therefore, immediately after treatment.

An advantage of the use of ammonia with chlorine, is that in small plants, without full-time attendants where the flow or usage of water varies materially from hour to hour, and where the chlorine dosage is not regulated by automatic equipment in accordance with the volume of flow, the heavier dosages during periods of low flow are less likely to cause tastes.

Because the ability to disinfect is retained for longer periods, ammonia-chlorine is advantageous for prechlorination at filter plants to control algae and slime growths in settling basins and filters.

Ammonia is ordinarily furnished in cylinders of the same type as are used for chlorine; and application is by means of equipment practically the same as that used for applying liquid chlorine. Chlorinators cannot be used, however, since different metals are necessary to prevent corrosion.

The dosage of ammonia required depends on the characteristics of the water. Ordinarily it is 1/3 to ½ of the chlorine dosage. When using ammonia, a higher chlorine dosage is commonly used—sufficient to maintain a residual of about 0.4 p.p.m.

The use of the orthotolidine test on waters treated with ammonia and chlorine has already been discussed.

Super-Chlorination and Dechlorination

When phenols are present in the water, small doses of chlorine cause disagreeable tastes; but when a much larger dose is applied—1 to 1.5 p.p.m., the tastes are reduced or destroyed. This treatment may cause chlorine tastes, due to the excess chlorine remaining in the water. When this occurs, the water must be dechlorinated, which can be accomplished by adding sodium thiosulphate, sulphur dioxide, sodium bisulphite, activated carbon or black-alum.

Using Potassium Permanganate

There has been some use of potassium permanganate for destroying phenols

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likely to cause taste; but there is always the possibility that it will, of itself, cause tastes when used in a quantity sufficient to eliminate the phenols.

This chemical has also been used to oxidize organic matter when this occurs in water in sufficient quantity to materially increase the demand for chlorine. An application of not to exceed 0.2 p.p.m. will reduce the chlorine demand of water containing much organic matter and generally lessen the possibility of producing chlorinous tastes by chlorination.

How Hard Water Is Softened

The causes of hardness—calcium and magnesium compounds — have been stated in the section on laboratory methods and tests. In the amounts ordinarily present in water, these chemicals do not affect health, but they do interfere with the use of water for many business, domestic and industrial uses. Hardness greatly increases the amount of soap used; reduces the efficiency of hot water heaters and boilers by depositing scale on tubes and heating surfaces; and may hinder the operation of laundries, textile plants and other industrial processes.

Softening is usually effected by one of two processes: The addition of lime and soda ash, which change the bicarbonates and sulphates of calcium and magnesium from soluble to insoluble forms, and the removal of these by sedimentation and filtration; and by passing the water through a bed of zeolithe, which transforms the calcium and magnesium salts into sodium compounds which do not cause hardness.

Lime-Soda Softening

To soften water by the application of lime and soda ash, the chemicals are added to the water and mixed thoroughly, as with coagulating chemicals; the treated water is allowed to settle, and then filtered. The settling period should be somewhat longer than in coagulation to remove turbidity. Softening can be combined with coagulation and sedimentation, frequently resulting in increased efficiency for the filters, because the precipitate formed is much more bulky, especially when magnesium compounds are present. Color, when present in sufficient amounts to be troublesome, should be removed before softening, as a rule.

Lime is added to remove the carbonate hardness and the magnesium; soda ash to remove the non-carbonate hardness. Data required are:

Free CO_2; half-bound CO_2 which is 44% of the bicarbonate alkalinity; total magnesium; and non-carbonate hardness. These should be expressed in parts per million.

The free and the half-bound CO_2 are added together; 10.62 pounds of pure CaO are required per million gallons to neutralize each part per million of free and half-bound CO_2.

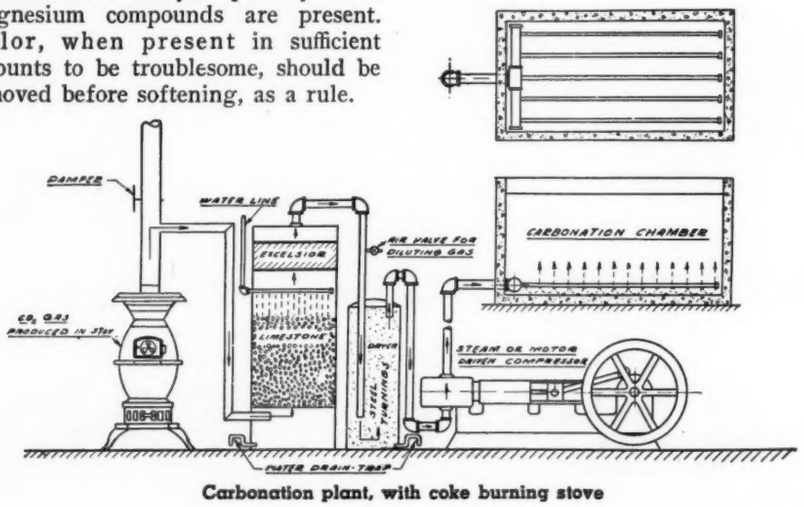
For instance, if the free CO_2 is 10 p.p.m. and the methyl orange or erythrosin alkalinity is 150 p.p.m., CaO required will be:

$(10 + 150 \times .44) \times 10.62 = 76 \times 10.62 = 810$ lbs. per m.g.

If the lime use is 90% CaO, the amount required will be $810 \div .90 =$ 900 lbs. per m.g.

The lime required to react with magnesium amounts to 19 pounds of CaO per million gallons per part per million of magnesium. Thus, if the total magnesium amounts to 21 p.p.m., CaO required will be $21 \times 19 = 399$ lbs. per m.g.; and if the lime is 90% CaO, the amount required will be $399 \div .90 = 443$ bs. per m.g.

For the removal of non-carbonate hardness, 9 lbs. of soda ash are required per million gallons per part per million of non-carbonate hardness, expressed as $CaCO_3$. Thus, if the non-carbonate hardness is 95 p.p.m., the amount of 100% soda ash required will be $95 \times 9 = 855$ lbs. per m.g.



Carbonation plant, with coke burning stove

It is usual to leave a carbonate hardness of 35 p.p.m. to 50 p.p.m. and a total hardness of 50 to 100 p.p.m. In practice this amount should be subtracted before computing the chemical dosage. For instance, if the non-carbonate hardness is 95 p.p.m., and it is desired that the treated water should contain 50 p.p.m. of non-carbonate hardness, the soda ash required will be:

$(95 - 50) \times 9 = 405$ lbs. per m.g.

Jar tests, already described, may be used to check the calculations of lime and soda ash.

When water is softened with lime, some of the carbonates remain in suspension in the water, and precipitate on the sand grains of the filter or in the piping of the distribution system. This is especially the case when the excess lime treatment is used, which consists of overdosing the water with lime—35 to 50 p.p.m. excess of lime—resulting in a very rapid formation of flocculent matter.

This excess dosage of lime results in a caustic alkalinity. This can be remedied by the addition of soda ash, converting the excess calcium hydroxide to caustic soda; but this may cause foaming in boilers, and does not improve the taste of the water.

The addition of carbon dioxide will also remedy the caustic alkalinity, changing the calcium hydroxide to calcium carbonate. This is known as recarbonation.

The CO_2 for the small plant is generally produced by burning gas, oil or coke; stack or produce gases can be used. For burning oil, gas or coke, a small stove may be used, the gas from which contains about 10% of CO_2. This gas must pass through a washer, a drier, a trap for further removal of the moisture and a compressor or blower, which forces it through a grid or diffuser into the water. Porous diffuser plates reduce depth of basin and power cost of CO_2 diffusion.

The CO_2 required in pounds per million gallons is 3.7 times the parts per million of calcium carbonate. For a plant with a capacity of 1 m.g.d., requiring 500 pounds of CO_2 daily (about the maximum required) about 30 cubic feet per minute of gas will be required. A full treatment of this subject is given in Water Supply and Treatment, by Charles P. Hoover, published by the National Lime Association.

Zeolite Softening

Zeolites are mineral compounds which have the ability, when water is passed through them, of removing the hardness. In reality this is an exchange. The zeolites normally have a sodium base, but when water containing calcium and

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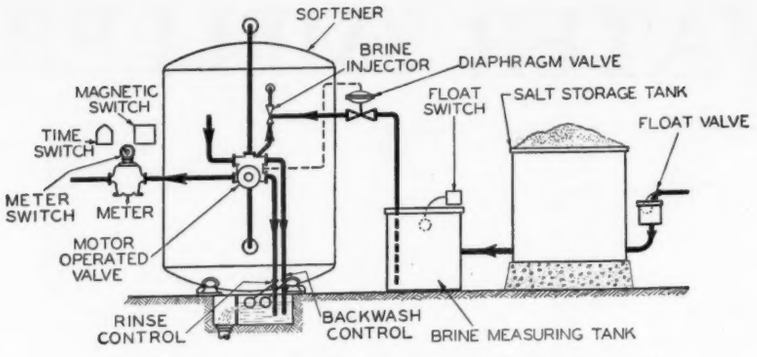

An automatically controlled zeolite softening plant (Permutit)

magnesium is passed through the zeolites, the sodium is given up and its place is taken by the calcium and magnesium which are taken from the water. When all the sodium has been replaced by calcium and magnesium, the zeolite must be regenerated, which is accomplished by passing a strong salt solution through it. The calcium and magnesium is now exchanged for sodium, the bed of zeolite is washed, and is again ready for softening water. This process is continued indefinitely.

The zeolite, which generally resembles a green or whitish sand, is usually encased in a steel tank. The bed of zeolite is placed on a layer of gravel underneath which is the drainage system or on a system of porous plates, which eliminate the need for gravel. The bed of zeolite is usually 30 to 60 inches thick. The washing system is generally the same as in a rapid sand filter, though the rate of wash is usually lower—from 6 to 8 gallons per square foot per minute.

The rate of operation is greater than with rapid sand filters—ordinarily 4 to 6 gallons per square foot per minute. The zeolite is not intended to act as a filter, nor to remove suspended matter from the water. Consequently only clear water should be passed through the zeolite, and in the case of filter plants, softening will normally follow filtration.

The rock salt for regenerating the zeolite is made into a brine, which contains about 25% of salt—a gallon of the solution containing nearly 2½ pounds of salt. As applied to the zeolite for regenerating, the brine should contain not more than 10% nor less than 5% of salt.

In regenerating, the incoming water is shut off, the outlet closed, the unit backwashed, and the brine introduced. It is either held in contact for a few minutes—10 to 15—or circulated slowly through the bed.

After regeneration, the beds are put back into service. Sometimes the water is wasted until the effluent shows a hardness of about 17 p.p.m.

Zeolites will soften water to zero hardness, but this is not often desirable, and a hardness of 50 to 70 p.p.m. is generally permitted. This is usually accomplished by softening completely a part of the water and mixing this softened water with the remaining unsoftened water to obtain the desired results.

Occasional tests are made on the water when the zeolite, as shown by experience, is losing its ability to remove hardness so that the regeneration process can be applied. The soap test is frequently used for this purpose.

Zeolites will also remove iron and manganese, even for a time after the ability to remove hardness is lost. This will be discussed in the section on iron and manganese removal.

Algae Identification and Control

Plant growths of the algae type may create trouble in several ways — by causing tastes and odors, by giving the water a colored appearance, and by tending to clog filters or other treatment processes. In addition, other microscopic organisms in water may contribute to these troubles or cause some all their own.

The microscopic organisms in water include the algae, fungi and archigomatae, all of which are plants; and the protozoa, rotifera, crustacea, vermes, and various others, which are animals.

The term plankton is often used to designate the above organisms. Strictly speaking, the term refers to organisms that float free in the water, but it has been extended to include those organisms, exclusive of bacteria, that are found in the open waters of lakes and streams.

There are 6 commonly recognized classes of algae: Cyanophyceae, or blue green; chlorophyceae, or green; xantophyceae, or yellow green; diatomaceae, or diatoms, usually brown; the phaetophyceae, or brown; and the rhodophyceae or red. Each of these classes are still further subdivided.

Only sunlight and carbon dioxide are necessary for the growth of algae in water. Such growths are most prevalent during warm weather. Therefore, as the temperature of the water increases in the early summer, frequent examinations of the water should be made so that preventive treatment can be instituted before the growths have become sufficiently numerous to be troublesome.

It is desirable that such treatment be based on actual knowledge of algae growth conditions. This is best obtained by a microscopical examination to determine the kind and number of organisms in the water. With such knowledge, treatment may begin as needed. But if facilities for this examination are lacking, algae control, in the northern part of the United States, should generally start about May 1 and continue till about Nov. 1.

Microscopical Examinations for Algae Growths. A sample of about two liters of the water should be taken, using a clean container, from a point where the organisms will be as representative as possible. The container should be inserted with the neck downwards about a foot below the surface of the water, then inverted and allowed to fill. For greater depths, special sampling devices are necessary. The sample should be examined within 6 to 8 hours; if this is not possible, it should be preserved by adding 20 ml. of formalin for each liter of water in the sample.

If the sample of water contains a large number of organisms, it can be examined microscopically without concentration. If the number of organisms is small, the sample should be concentrated by filtering or centrifuging. The Sedgewick-Rafter method of concentration is simple and inexpensive. The process is as follows:

A Sedgewick-Rafter funnel of 500 ml. capacity is fitted at the bottom with a ½-inch one-hole rubber stopper. A small glass U-tube is inserted in the stopper so that the outer arm extends 1 inch above the small end of the stopper. A ⅜-inch diameter cloth disc, preferably of silk bolting cloth, is then inserted, so that it lies flat on the rubber stopper. White sand of 60 to 120 mesh is then poured into the funnel to a depth of ½ inch; 5 to 10 ml. of distilled water is then used to wash down any sand adhering to the walls of the funnel and to drive the air out of the sand.

The sample to be concentrated is then mixed by gentle agitation and 250 to 1,000 ml. is accurately measured out for concentration. The size of this sample depends upon the number of the organisms in the sample. The funnel should

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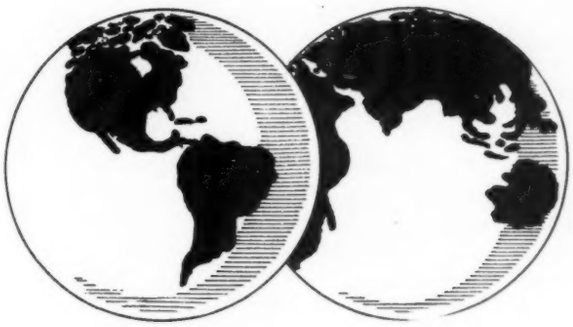

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be held in a slanting position, the measured sample of water poured slowly into the funnel, and allowed to filter through the sand. If necessary, moderate suction may be employed. Occasionally during the period of filtration the sides of the filter should be washed down with distilled water. When the water has reached the level of the U-tube, this tube is removed to allow most of the remaining water to drain through the sand.

The rubber stopper is then removed and the sand transferred to a small beaker. The walls of the funnel are washed with 5 ml., 10 ml., or more of distilled water. This washwater should be collected in the beaker containing the sand. The water and sand are well, but not violently, mixed and after a moment for settling, the water is decanted immediately into a beaker.

This concentrate is mixed by a rotary motion and one ml. is transferred to a counting cell. The cover glass should then be slid into position so that the entire cell is covered. After allowing this cell to stand for a few minutes, it is placed under the microscope for examination.

The microscope should be capable of magnifications of from 60 to 400. The degree of magnification used depends upon the type of organisms present and whether the organisms are being counted or identified. In the examination of the larger organisms a 48 mm. objective is used. For the counting of small organisms and identification of different types, a 16 mm. objective is used in order to obtain the higher magnification.

For counting the organisms, the cell employed is such that the depth of the sample under examination is 1 mm. The proper magnification should be such that the stage covered by the micrometer is exactly one square millimeter; and since in the standard field each cell covers 1/1000 mm. of the sample or concentrate, by counting the total organisms in 10 fields, 1/100 mm. of the sample or concentrate will be covered. The 10 fields counted should be well distributed over the entire cell. The total micro-organism count in a sample is recorded as the number of standard units per ml. without regard to the type present. This number is calculated as follows:

Let a = number of units counted
b = total number of fields in counting cell
c = number of fields counted
d = number of mls. of concentrate
e = number of mls. of water filtered

Then $a \times \frac{b}{c} \times \frac{d}{e}$ = units per ml.

A count of 500 units per ml. will in general cause taste and odor troubles and a count of 400 units per ml. indicates the necessity for treatment.

Dosage of Copper Sulphate Likely to Kill Fish*

Fish	*Parts per Million*	*Pounds per Million Gallons*
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.36	11.1
Black Bass	2.00	16.6

*Moore, G. T., and Kellerman, K. F. Bul. No. 76, Bur. Plant Indus. U. S. Dept. of Agri. (1905).

The cost for the minimum of equipment needed for this work is less than $75. Methods for microscopical examination of water are covered in greater detail in *Standard Methods of Water Analysis*. The identification of algae types requires considerable experience and at first will require reference to illustrations of the various types. A complete treatment, and a large number of illustrations will be found in *Microscopy of Drinking Water* by Fair & Whipple.

Copper Sulphate Treatment

Prevention or control of algae is necessary in both storage and distributing reservoirs. Growths may be killed by the use of copper sulphate or chlorine. The latter, while easy to apply within a treatment plant, is quite difficult to apply in reservoirs, consequently copper sulphate is almost universally used for algae control in these. In the table herewith the more troublesome algae types are listed, with their odor characteristics, and the amount of copper sulphate required for treatment.

A proper dosage of copper sulphate should be applied as insufficient dosages are ineffective. A concentration sufficently high to be injurious to health would have such a disagreeable taste that it would be practically impossible to drink it. However, the dosage necessary for control of algae may be sufficient to kill fish. Therefore, if fish are present in the water to be treated, it is advisable to consult the table herewith which shows the resistance of various species of fish.

Application of Copper Sulphate.—The most common procedure is to place the copper sulphate crystals in bags which are then dragged behind boats. In some cases perforated metal boxes or buckets have been utilized in place of bags as containers for the copper sulphate. Where the body of water is too shallow to allow ready access by boat to the affected areas, or is very small, a bag of copper sulphate may be suspended in the center of an inflated inner-tube and dragged around over the surface of the water with a rope attached to the tube.

Since algae growths are more profuse in shallow areas, all of these areas should be reached in the treatment. This can be accomplished by zigzagging the boat back and forth, gridironing, or otherwise so routing the boat that the paths of travel are 20 to 100 feet apart.

The continuous application of copper sulphate to reservoirs during the warmer months, as a concentrated solution to the water entering the reservoir, has been successful in preventing growth. A relatively small dosage is usually sufficient.

COPPER SULPHATE REQUIRED FOR TREATMENT OF MICROORGANISMS*

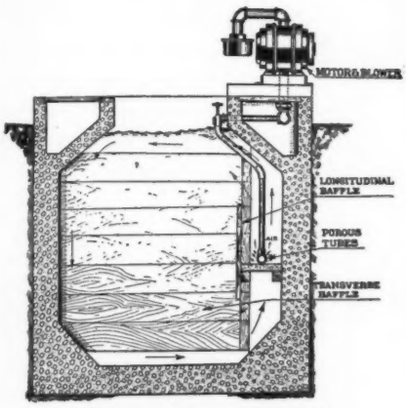
Organism	*Odor*	*P.P.M.*	*Lbs. per M.G.*
Asterionella	Aromatic, geranium, fishy	0.12-0.20	1.0-1.7
Synedra	Earthy	0.36-0.50	3.0-4.2
Tabellaria	Aromatic, geranium, fishy	0.12-0.50	1.0-4.2
Eudornia	Faintly fishy	10.0	83.2
Hydrodictyon	Very offensive	0.10	0.8
Pandorina	Faintly fishy	10.00	83.0
Volvox	Fishy	0.25	2.1
Anabaena	Moldy, grassy, vile	0.12	1.0
Aphanizomenon	Moldy, grassy, vile	0.12-0.50	1.0-4.2
Clathrocystis	Sweet, grassy, vile	0.12-0.25	1.0-2.1
Coelosphaerium	Sweet, grassy	0.20-0.33	1.7-2.8
Cylindrospermum	Grassy	0.12	1.0
Ceratium	Vile	0.33	2.8
Cryptomonas	Candied violets	0.50	4.2
Dinobryon	Aromatic, violets, fishy	0.18	1.5
Glenodinium	Fishy	0.50	4.2
Mallomonas	Aromatic, violets, fishy	0.50	4.2
Peridinum	Fishy, like clam shells	0.50-2.00	4.2-16.6
Synura	Cucumber, muskmelon, fishy, bitter	0.12-0.25	1.0-2.1
Uroglena	Fishy, oily, cod liver oil	0.50-0.20	0.4-1.6
Beggiatoa	Very offensive, decayed	5.00	41.5
Crenothrix	Very offensive, decayed	0.33-0.50	2.8-4.2
Sphaerotilis natans	Very offensive, decayed	0.40	3.3

*Hale, Frank E., "The Use of Copper Sulphate in Control of Microscopic Organisms," Nichols Copper Co., New York.

Methods of Taste and Odor Control

Tastes and odors do not cause disease and rarely indicate dangerous contamination. But when they render a supply unpalatable, the consumer is likely to turn to other supplies, often less safe, as wells, springs or bottled water. To protect the health of the community by furnishing a safe and a palatable water at all times is the duty of the water official. It is also good business.

Sources of Tastes and Odors.—The most common sources of tastes and odors in water supplies are plant growths of the algae type. Some of these organisms exude oils or decomposition products which impart a disagreeable taste to the water, especially in combination with chlorine. Decaying vegetation, as leaves, grass and moss, is often a contributing cause.



Spiral-Flow Aerator (Link-Belt).

These are particularly evident when reservoirs are low, and contain swampy or stagnant areas.

Severe and troublesome taste and odor conditions are often due to industrial wastes from coke plants, chemical plants, canneries, tanneries, oil refineries, and dairies.

Methods of Control.—The prevention of tastes and odors in the water may be accomplished by preventing the formation or growth of substances that may cause taste, as in the case of algae; by preventing the entrance of industrial wastes into the supply; by neutralizing or destroying the taste and odor-producing substances; or by removing them. Local conditions will usually determine which of these methods or combinations of them will be most effective and economical.

Preventive Measures.—Every measure possible should be taken to eliminate at the source all conditions tending to cause tastes and odors. An early step, as already stated should be a complete and thorough survey of the entire water shed to determine the points where pollution may originate.

Preventing the entrance of industrial wastes into the supply is not always practical, since the expense of treatment may be too great. The waste causing the trouble, which may be only a small part of the total waste produced, can often be treated or disposed of separately; or even stored and discharged during high water periods.

Swampy and stagnant areas should be eliminated as far as possible, since decaying vegetation and leaves may contribute high color as well as disagreeable tastes and odors. In eliminating these, the better procedure is to either fill or deepen them; to arrange for proper drainage; to build channels to carry the fresh water around or through the affected areas; or the stagnant water may be cut off by means of dykes or other embankments.

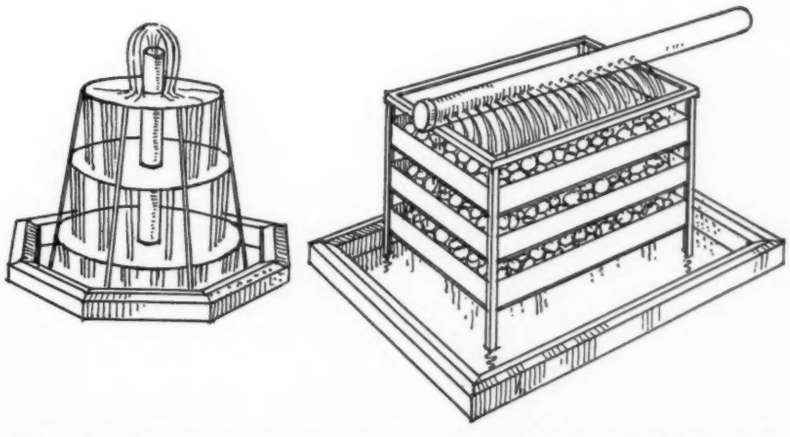
Corrective Treatments.—Preventive measures are not always effective or possible. When they are not, corrective measures must be used. These include the following: Aeration; prechlorination; superchlorination; potassium permanganate; blackalum; bleaching clay and activated carbon.

Tastes due to necessary heavy chlorine applications, and their prevention by the use of ammonia, or by super and dechlorination have been considered previously; also the use of potassium permanganate.

Aeration.—By exposing a large surface area of the water to air, aeration liberates such gases as hydrogen sulphite and carbon dioxide from the water and permits the oxygen in the air to come in more intimate contact with the finely divided water particles, thus increasing the dissolved oxygen content of the water. This increase of oxygen content tends to remove the offensive tastes and odors by oxidation. Aeration has other uses also, as reduction of iron and manganese.

Water is aerated by spilling over the trays.

The general types of aerators in use include: (1) The cascade type, where the water is allowed to flow over successive sets of weirs in a step arrangement or past baffles set in the path of the water so that the direction of water flow is continually being changed, the water being agitated meanwhile; (2) The diffusion method, which consists of blowing air under a slight pressure through porous plates which are so constructed that a flow of small air bubbles rises through the water continually. This usually requires a tank construction, but is economical and efficient; (3) The spray method, in which the water is discharged under pressure through nozzles so that the water is forced into the air in a fine spray. This is the most commonly used method; (4) The surface contact type, which consists



These illustrations show two types of aerators. At the left is the splash type; at the right, the coke tray. (Courtesy National Lime Ass'n and Charles P. Hoover)

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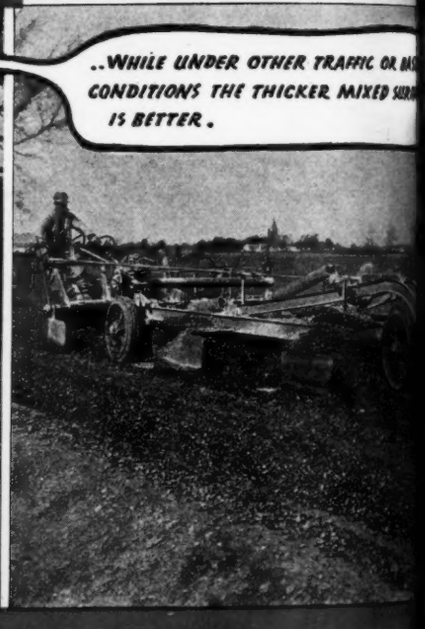
BETTER RESULTS

Tarmac

MAKES GOOD ROADS

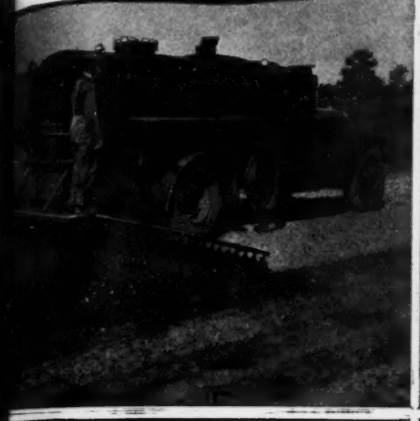
. . . AN INTERVIEW



FOR SALE: **Tarmac**—THE ROAD WITH THE HIGH COEFFICIENT OF SAFETY

ITH A SUCCESSFUL HIGHWAY OFFICIAL

. . . . . OUR NEW CONSTRUCTION IS BUILT WITH TARMAC, WHICH WE HAVE FOUND GUARANTEES A LASTINGLY SKID-RESISTANT SURFACE, AND . . . . . .



OLD SLIPPERY ROADS OF OTHER TYPES HAVE BEEN MADE SAFE WITH INEXPENSIVE TARMAC TREATMENTS.

MR. JONES, ARE THESE SMOOTH-RIDING TARMAC ROADS ALL BUILT ALIKE?

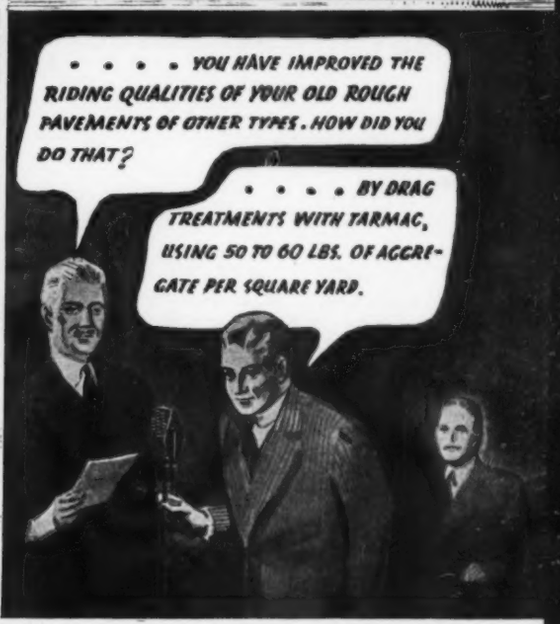
. . . . WHY DO YOU USE TARMAC FOR YOUR BITUMINOUS WORK?

. . . . . BECAUSE WE FIND THAT FOR PRIME COATS, TARMAC NOT ONLY PENETRATES, BUT AT THE SAME TIME BINDS TOGETHER THE SURFACE PENETRATED

WHILE FOR MIXED SURFACES, TARMAC MIXES MORE READILY WITH OUR LOCAL AGGREGATES AND, IN ALL TYPES, THE FINAL TARMAC SURFACE LASTS LONGER AND IS SAFER THAN ANY OTHER TYPE.

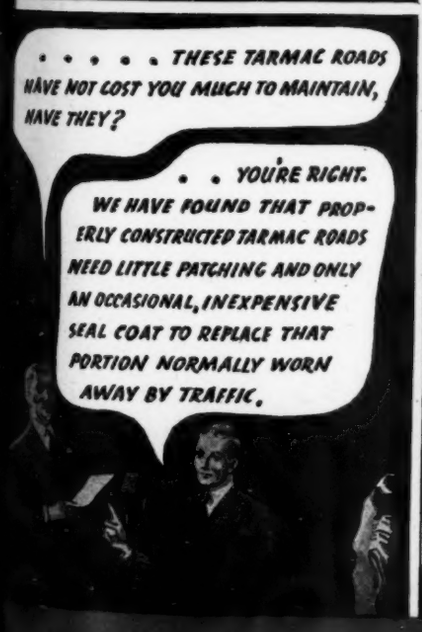
. . . . YOU HAVE IMPROVED THE RIDING QUALITIES OF YOUR OLD ROUGH PAVEMENTS OF OTHER TYPES. HOW DID YOU DO THAT?

. . . . BY DRAG TREATMENTS WITH TARMAC, USING 50 TO 60 LBS. OF AGGREGATE PER SQUARE YARD.



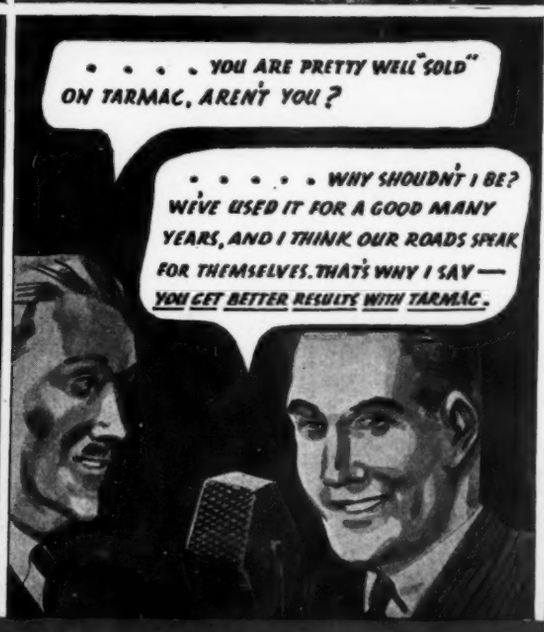
. . . . . THESE TARMAC ROADS HAVE NOT COST YOU MUCH TO MAINTAIN, HAVE THEY?

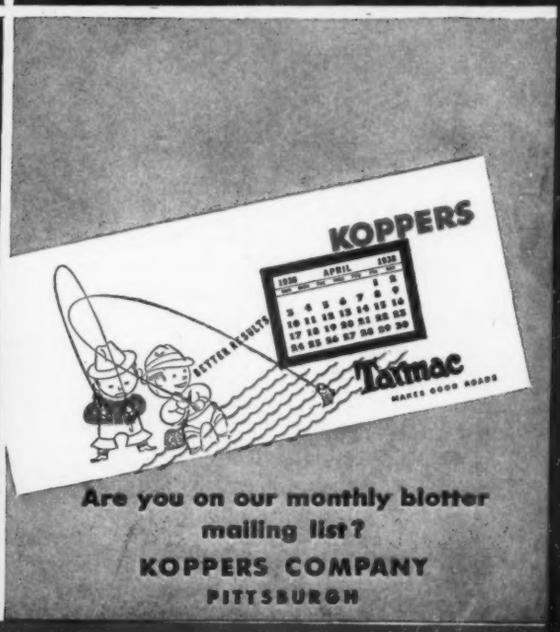
. . YOU'RE RIGHT. WE HAVE FOUND THAT PROPERLY CONSTRUCTED TARMAC ROADS NEED LITTLE PATCHING AND ONLY AN OCCASIONAL, INEXPENSIVE SEAL COAT TO REPLACE THAT PORTION NORMALLY WORN AWAY BY TRAFFIC.



. . . . YOU ARE PRETTY WELL "SOLD" ON TARMAC, AREN'T YOU?

. . . . . WHY SHOULDN'T I BE? WE'VE USED IT FOR A GOOD MANY YEARS, AND I THINK OUR ROADS SPEAK FOR THEMSELVES. THAT'S WHY I SAY — YOU GET BETTER RESULTS WITH TARMAC.





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of coke-filled trays through which the water is passed.

Aeration affects only a few of the taste-producing elements. It should be chosen for this use only after analyses and investigations of the water have shown clearly that aeration will be effective under the conditions that actually exist. A recent development is a combination of aeration and activated carbon, which appears effective in odor reduction.

Bleaching Clay or Fullers Earth. — Bleaching clays have been utilized in some plants for correction of tastes and odors. The removal principle in the case of activated clay is the ability of the clay particles to adsorb the taste and odor-producing substances. The powers of adsorption of the clay particles apparently are limited to a few compounds, especially those present in petroleum refining wastes. Application is by dry or solution feed to raw water, either with aluminum sulphate, before or after, as results indicate.

Activated Carbon and Aluminum Sulphate.—The continuous use of an activated carbon compounded coagulant is also helpful in preventing tastes and odors caused by putrefying sludge in setting basins. In addition to the effect on odor, there is often an increase in length of service between basin cleanings.

Activated Carbon.—Activated carbon, generally used in powdered form, is applied by means of dry feed machines, solution feed machines or mixed with other chemicals. In dry feeding, equipment specifically designed for this material should be used, since activated carbons are much lighter and finer than other chemicals commonly employed in water treatment. Important factors in dry feed equipment are:

Sufficient agitation in the hopper to insure a constant flow to the feeding control mechanism. Design of solution pot so that intimate and violent mixing of the carbon with the water is obtainable. Use of a water ejector to carry flow from solution pot. The lines beyond the water ejector should be straight to eliminate back pressure and deposition of the carbon in the lines. Rubber hose has been found effective since the flows are fairly uniform and deposits of the carbon can be broken loose by a sharp blow on the hose.

Activated carbons are not soluble in water, but solution methods can be used, the particles being carried in suspension to the point of application. Thorough agitation is necessary, since it is difficult to completely wet the carbon particles. The solution tank should be equipped with an agitator for mixing to prevent the carbon particles from settling. Orifice feed methods are not satisfactory, as there is occasional stoppage of the orifice. A siphon arrangement is better.

Activated carbon may be mixed and fed with alum or lime in the same dry feed machine. Activated carbon should not be mixed with hypochlorite or other chlorinous compounds, as the result may be a fire or explosion.

Points of Application. — Where filter plants are a part of the purification process, activated carbon is applied at any point prior to the filters. It may be applied as a thin, watery slurry directly on top of the filters, to the filter influent, part way through the coagulation basin, at the entrance to the coagulation basin, in the mixing basins, or the raw water. In general the points of application are divided into two general classifications, namely, prior to coagulation, and following coagulation.

In any case the points where the carbon is to be applied should be such that thorough mixing is assured so that the carbon will be properly distributed throughout the body of water to obtain as intimate a contact as possible of the carbon particles with the taste and odor producing substances present. For example, if it is found that the most effective results are accomplished by application prior to coagulation, the carbon may be applied at the suction side of the pump, as in passing through the pump thorough mixing of the carbon particles with the water is insured.

Due to the variations in types of tastes and odors in water, and in plant design, it is difficult to make definite recommendations as to the most satisfactory point to apply the activated carbon.

If applied after coagulation the activated carbon will have the least work to do, since there is usually some elimination of tastes and odors during the sedimentation process. This point of application is recommended: (1) where tastes and odors are of short duration; (2) where tastes and odors appear suddenly and have not been noted until they have penetrated fairly well through the plant; (3) where tastes and odors are very mild.

Application prior to coagulation insures a longer contact time for the carbon to do its work and to accomplish other incidental benefits. This point of application appears to be most suitable for the following: (1) where tastes and odors occur continually or frequently; (2) where the organic content of the water is relatively high and may cause tastes and odors due to decomposition within the plant itself; (3) where tastes and odors are of a severe nature, requiring heavy dosages of activated carbon. A split treatment may be preferable for serious tastes.

Incidental benefits may include; better coagulation, better control of coagulation, greater uniformity in chlorine demand of the water, stabilization of sludge in the sedimentation basin, longer intervals between cleanings of the sedimentation basin and longer filter runs.

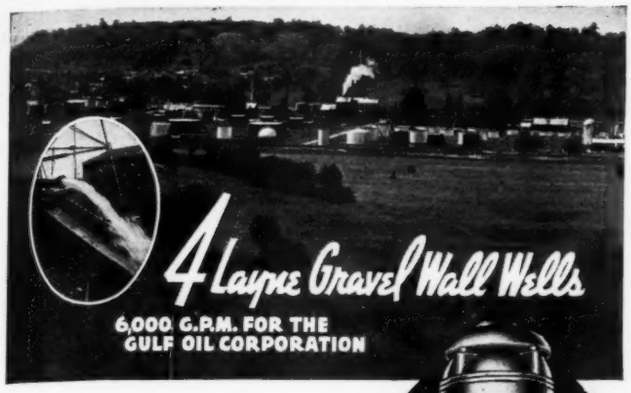
Dosages of Activated Carbon.—The required dosages of activated carbon have varied from as low as 1 lb. per million gallons to as high as 560 lbs. per million gallons. However, calculations based on a survey reported in the March, April and May, 1936, issues of PUBLIC WORKS indicates that the average proportion being employed is approximately 16 lbs. per million gallons.

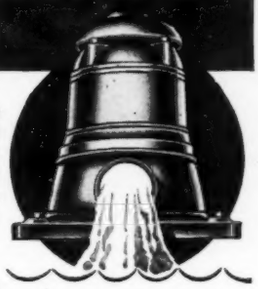
Application to Reservoirs. — Activated carbon in the powdered form can be applied to reservoirs, the only requirements being that the reservoir so treated be taken out of service for a period of preferably 48 hours. The method of application consists of first mixing the carbon thoroughly with water in a suitable container, such as a drum, and then scattering the suspension of carbon slurry over the surface of the reservoir from a boat. The carbon suspension should be so applied that as uniform a dosage as possible is applied to all of the water in the reservoir. In other words, more carbon should be applied at the deeper sections than is applied in the shallow areas. Better settling of the carbon is obtained if the application follows within a day or so a copper sulphate treatment of the reservoir. The objection to the application of activated carbon to a reservoir which is kept in service is that the small particles of activated carbon will get into the distribution system. This may result in complaints on the appearance of the water for a day or so, but is not harmful in any way to the consumers.

Granular Activated Carbon Filters. —Activated carbon in the granular form is also used in pressure filters. This type of treatment is particularly suited to small water systems, industrial plants, and small municipal installations.

Iron and Manganese Removal

The presence of iron in the amount of 0.3 to 0.5 p.p.m., is shown in the water by rusty or brown stains on plumbing fixtures, and also by stains on articles washed in the water. Growths of crenothrix, or iron bacteria, may occur in the pipes of the distribution system. Manganese produces generally similar effects.





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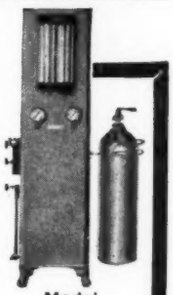
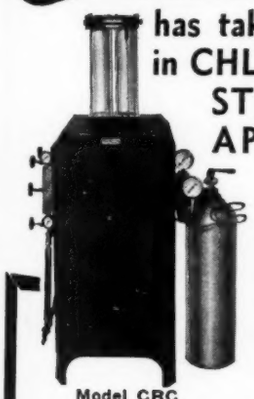

Model PRC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Today, water-borne diseases have been reduced almost to a minimum. The story of this accomplishment with its saving of lives by the millions —is one of the great achievements of the ages.

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(**"The Old Oaken Bucket" by Samuel Woodworth*)

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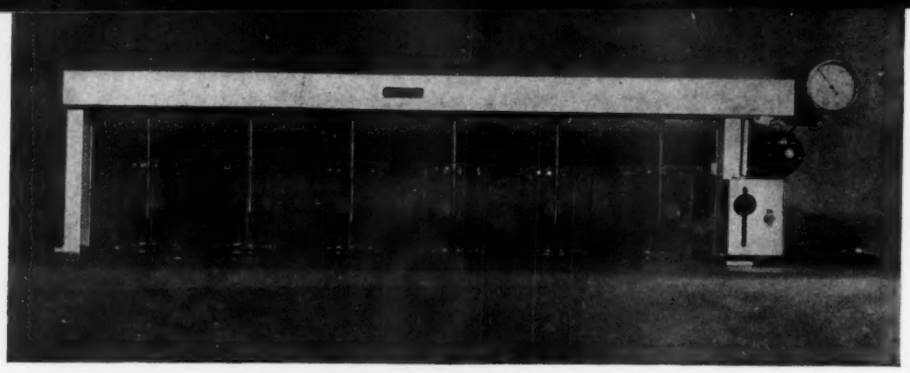
For descriptions of helpful booklets and catalogs, see pages 79-81.



The Phipps & Bird 6-jar stirrer is handy for laboratory work

The principal methods of removal are by oxidation or by passing through zeolites; other methods include aeration, treatment with lime and alum, passage through contact beds of broken stone, coke, etc., and filtration—preferably through rapid sand filters since these are preceded by coagulation and sedimentation, which aids in removal.

Iron is usually present as ferrous bicarbonate ($Fe[HCO_3]_2$) or ferrous hydroxide ($Fe[OH]_2$), and manganese as manganese hydroxide ($Mn[OH]_2$) or sulphate ($MnSO_4$) or as the chloride ($MnCl_2$).

Various aerating devices have been mentioned in connection with treatment for taste and odor removal. Blowing air through porous plates, spraying into the air by means of nozzles, or the use of trays, steps of pans so that the water falls over these in thin sheets, are most common. Air lift pumps commonly provide sufficient air when these are used in handling the water. And since only a small amount of air is needed when there is no CO_2 present—about one-seventh the amount of iron present—this can sometimes be provided by admitting this into the suction of the pump. With much CO_2 present, this cannot be done.

The effect of aeration is to render the iron insoluble, in which form it can be removed in part by sedimentation and wholly by filtration.

Manganese, under some conditions, will not oxidize as readily as iron, and when present with iron may interfere with its removal by aeration.

In acid waters, iron and manganese, may require the addition of enough lime to raise the pH above 8 or even 9 before aeration.

The ordinary zeolites used for softening water remove soluble iron and manganese simultaneously with hardness, and will even continue to remove them for a time after their capacity to remove hardness fails. Special zeolites are also provided, as manganese zeolite, which is a sodium zeolite converted by manganous chloride to manganous zeolite, and then oxidized by sodium or potassium permanganate, which is used for regeneration.

Insoluble forms of iron or manganese will tend to clog the zeolite; therefore iron-bearing water should not be aerated before passing through the zeolite, and well waters containing iron should pass directly to the zeolite without exposure to air. When an air-lift pump is used on such waters, a period of sedimentation prior to treatment by zeolite should be provided.

As already stated, where zeolite softeners are employed, a part of the water only is softened and this is mixed with the unsoftened water to produce water of the desired hardness. When this is done, the portion of the water that is not softened can be passed through manganese zeolite to remove the iron and manganese.

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Sewage Disposal Construction Ordinances Sustained

The New Jersey Supreme Court (Crisci v. Board of Coms. of Raritan, 194 Atl. 445), held that the town came within the provisions of the Home Rule Act and therefore had authority to enact ordinances relating to its sewage and garbage disposal. One ordinance, of April 9, 1937, authorized the construction of an incineration plant. The other, of April 26, 1937, provided for an improvement of the town's sanitary sewer system by an extension of the existing system plus the construction of a sewage treatment plan, a pumping station, and an intercepting sewer. Both ordinances provided for acquisition of interests in land and for bond issues. The projects were further financed by a grant from the Federal Emergency Administration of Public Works. The contention rejected was that the town was incorporated for special and limited purposes only within which the ordinances could not be brought.

Damages for Flooding from Failure to Seal Sewers

In an action against a city for damages by flooding to groceries stored in a basement due to the city's failure properly to seal lateral sewers through which accumulations of water in an abandoned main sewer could flow, the California District Court of Appeal (Durante v. City of Oakland, 65 P. (2d) 1326) applied the general rule that municipalities have no power to create nuisances; and, where private property is flooded by the negligent construction of sewers or their negligent discontinuance, damages may be recovered. The defects complained of were held to come fairly within the provisions of the California Public Liability Act, and to be such that, in the event of heavy rains, injury to adjoining property would follow as a natural and probable consequence, which should have been foreseen by the municipal officers.

Know Your Subsoil Conditions Before Trenching

THE writer once, when building a sewerage system in a town where the soil was sand and clay, in some places combined and in others in alternate strata of various thicknesses, found, in opening up about 100 ft. of trench, that water appeared about two feet below the surface and that the sand, extending to a depth of 8 or 10 ft. where it rested on clay, contained so much water that one pump could not keep it down, and the banks caved in before they were deep enough to start sheeting. This stretch of sewer was on a comparatively level bench, from which a street sloped about a thousand feet to lower land. A sewer was being built up this hill to join the one on the bench, which had been started to keep another gang busy. After several days of struggling with the sandy soup, this trench was left temporarily. When the other sewer had been extended to the edge of the bench it was found (as had been thought) that the bench was really a basin of clay filled with sand which held the drainage water from above. As soon as the approaching sewer had cut through the edge of this basin the confined water drained rapidly down the sewer and in a week the trench across the bench was excavated without any pumping, or difficulty other than that caused by the previously caved banks.

Had the underground condition on the bench been known beforehand, much trouble and expense could have been saved and plans made for permanent drainage of the bench at little cost, by means of a subdrain under the sewer. Probably most engineers who have done any laying of underground pipes or conduits have run into conditions which caused them trouble and expense which could have been avoided had they been known beforehand. Rock, for example: most rock trenches, especially if the rock shatters badly, must be made wider than if in earth, or else the rock cut out by very expensive methods; and if no rock is anticipated and the trench is started narrow in the earth overburden, when rock is struck there is trouble aplenty.

In highway work a knowledge of underground conditions is desirable for another reason—to learn whether subdrainage is necessary and how best to provide it. Says H. E. Cotton, drainage engineer for Armco Culvert Manufacturers Association*: "Guessing at where to place subdrains has at times brought doubts as to their value. But it stands to reason that if free ground water is accurately located and then completely intercepted and quickly discharged, its harmful effects will be eliminated."

Knowledge of the presence and depth of ground water and the kind of soil within ordinary trench depth of the surface can often be obtained by use of soil augers. Borings have been made in favorable soils to a depth of 60 ft. Mr. Cotton describes how to make such an auger as follows: "A 1½" diameter wood auger bit (length of twist at least 7 to 8 inches) is welded to a section of ½-inch standard pipe to give an overall length of 3 feet. It is advisable to make the weld close to the twisted portion of the bit because the stem will bend easily. The end of the pipe is threaded to receive a standard tee with ¾-inch pipe stubs to form a handle about 15 to 18 inches long. Several extensions (two or three at least) should be provided of ½-inch pipe 3 feet long with threaded ends and couplers. Also it is convenient to have the pipe notched at 6-inch intervals to aid in measuring depth.

"Although heavier to transport, some engineers prefer to make the auger stem and extensions of ¾-inch extra-heavy pipe.

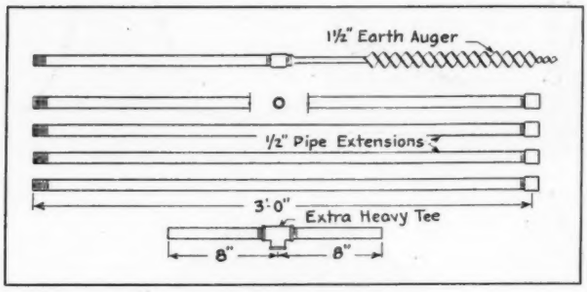

Diagram of Snell type of soil auger

Other Types of Augers

"Other types of auger bits may be purchased such as the Snell earth auger in diameters of 1 inch to 2½ inches. In soil containing scattered pebbles, this bit operates slightly better than the wood auger bit mentioned above.

"The post-hole auger such as the Iwan type is preferred by some because it operates better in soils containing pebbles. This auger may be obtained in sizes from 2 inches to 16 inches, but 2 inches to 4 inches is the range of sizes generally used by soil investigators.

"No auger bit can be operated successfully in stony soil. If not extensively stony, a post hole *digger* may be satisfactory for a depth of about 3 feet but otherwise hand excavated test holes are about the only alternative."

Where the depth of rock is the information desired, a pointed steel bar can be driven by sledges to a depth of 8 or 10 ft.; when it strikes rock (or a large boulder) the ring and "feel" of the bar tells it unquestionably. To make it easier to withdraw the bar it is well to upset and point the lower end. However, if the ground contains large gravel, the bull end may get wedged and very difficult to withdraw, and a plain pointed bar may be preferable, a jack being used to pull it out.

Another method is to make a wash boring, water being obtained under pressure from a fire hydrant or by means of a small contractor's pump.

Whatever the method of obtaining it, there are so many advantages of preknowledge of subsoil conditions before beginning any underground work, that we believe it is advantageous in many more instances than is generally realized.

*"Road Stabilization by Drainage," published by that association.

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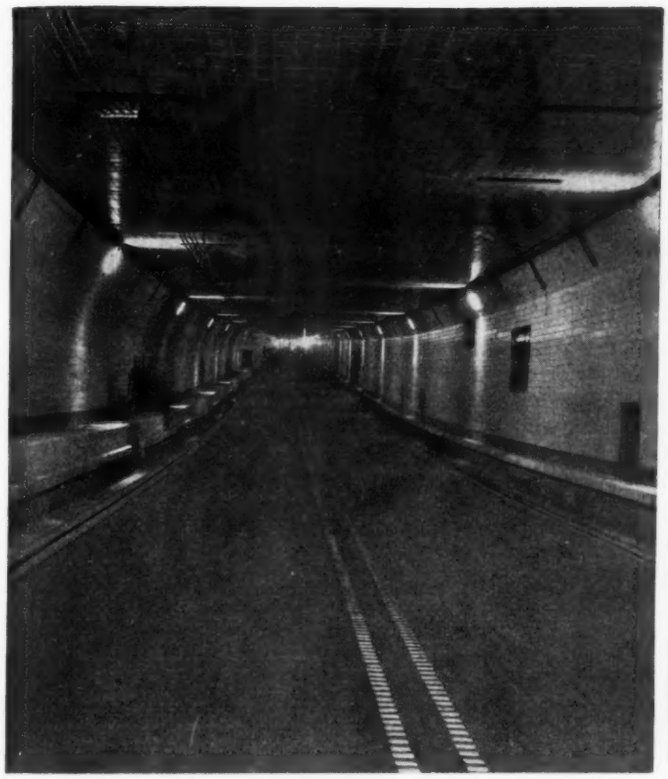

UNDER the Hudson River at 38th Street, New York City, the brick pavement in the new mid-town Lincoln Tunnel carries 500,000 cars, trucks, and buses monthly. The second tube is now being built. Later, Lincoln Tunnel will connect with a vehicular tunnel to be built under Manhattan Island.

Lincoln Tunnel is more than 8,000 feet long and cost $37,500,000. It was built by the Port of New York Authority which had previously used brick pavement on an approach of the Holland Tube. Brick's non-skid surface, durability and freedom from repair under concentrated traffic make it a wise choice.

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For descriptions of helpful booklets and catalogs, see pages 79-81.

Patching Concrete Pavements With Cement Bound Macadam

REPLACING broken areas in old concrete pavements with cement bound macadam has proved so successful in Kansas during the past few years that the state highway department is equipping two additional maintenance units for this work. Costs have averaged $4.29 per sq. yd., of which 15 per cent represents equipment rental, 44 per cent labor, and 41 per cent material cost. The completed patches have shown structural strength comparable to the original slab.

The first pavement to be patched with cement bound macadam was part of a 6-mile stretch of U. S. 40 west of Wamego, a road carrying heavy traffic. The broken areas — corner breaks along the centerline — had developed at seepy side-hill locations where the subgrade, a shaley clay, is plastic and unstable.

The first patching unit was organized in 1935, and experiments with various kinds of equipment were carried on during that summer. The equipment found most satisfactory consisted of an air compressor mounted on a truck, one jack hammer, and small tools, such as picks and shovels, for removing concrete from the broken areas; a light truck for carrying stone; another truck for sand, cement, and water; and a pneumatic-tired, stationary-drum, one-sack mixer equipped with receiving hopper and spout.

The air compressor crew cleans the holes ready for the placement of broken stone, then moves on; and the stone truck follows this crew and fills the holes. Grouting, the third step, is done as a separate operation.

One advantage of this type of repair demonstrated by the experimental work is the elimination of equipment concentration. Other advantages are: traffic hazards are reduced by filling the holes with broken stone immediately after the old concrete is removed; the crushed stone need be handled only once; and each operation can be carried on more or less independently of the other.

After concrete in the broken areas has been removed, the subgrade is excavated under the existing pavement to a depth of about 4 in. and 4 in. back from the hole edges to provide support for the old pavement. The old concrete is then broken up, replaced in the hole almost to the level of the old subgrade, and tamped in place with a jack hammer.

Crushed stone ranging in size from 1 to 2½ in. is deposited in the hole directly from the stone truck, and struck off, generally about half an inch higher than the pavement surface. Traffic is permitted to pass over the partially completed patch, eliminating the need for barricades.

The grouting crew completes the patch. Loose stone, whipped out by traffic, is first replaced, and the aggregate is leveled and sprinkled with water to facilitate the penetration of grout. A 1:2 mix, by weight, with a water-cement ratio of 7.5 gal. per sack of cement, has been found satisfactory for the work. With the sand used, this produces a grout having a flow of 20 to 21 seconds, when measured in the standard flow cone.

Stone displaced by grouting is tamped back in place with a tamping templet. The grouting crew then moves forward to the next patch.

Final tamping of the grouted patch is delayed from 30 minutes to an hour after grouting. This time varies with job conditions and prevailing temperatures. The elapsed time is as long as will permit leveling the patch to the plane of the pavement and flushing mortar to the surface for final finish. This delayed consolidation was found to reduce greatly shrinkage of the patch away from the pavement, as well as to facilitate final finishing.

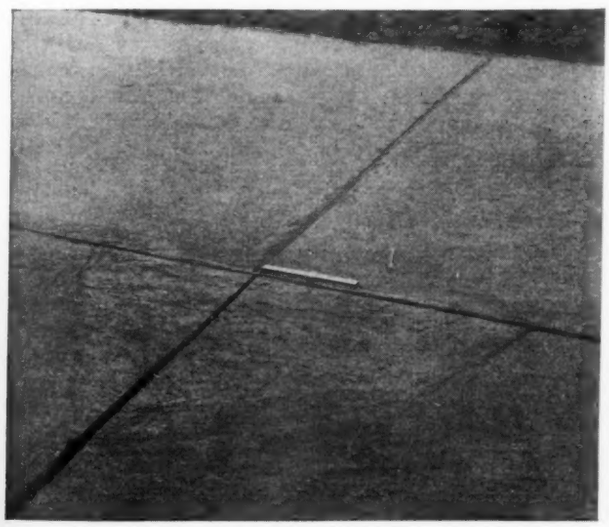
Final finish is applied with a wood float. The patch

Below, left, the crushed stone is deposited in the hole directly from the stone truck. Right, a receiving hopper and spout carry the grout directly to the patch.

Patches are given a final finish with a wood float and appear much the same as the original pavement.

is then cured under a double thickness of wet burlap. Grouting is done generally from 8 a. m. to 3 p. m. Traffic is allowed on the patches the next morning, the average age when opened to traffic being about 16 hours.

Test beams cast along the edge of the pavement have shown remarkably high strengths. An average modulus



The finished surface: There are practically no shrinkage cracks along the edges of the finished patch.

of rupture of 400 lb. per sq. in. was obtained at 42 hours, and 500 lb. per sq. in. at 90 hours.

Examination of patches after two years' service shows them to be in excellent condition, and reveals practically no shrinkage at the edges of the patches. In fact, most of them appear, to the casual observer, part of the original pavement.

Milwaukee Sludge Brings $20 a Ton

Sludge from the Milwaukee sewage treatment plant, sold under the name of "milorganite" since the plant first went into operation, is yielding an increasing income to partially offset the cost of treatment. In 1935 about 37,000 tons was sold at about $10. This year the price is $20 a ton, and J. L. Ferebee, chief engineer of the sewerage commission, estimates that about 42,500 tons will be sold this year.

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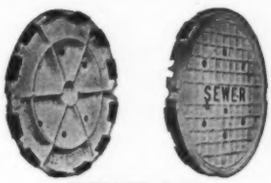

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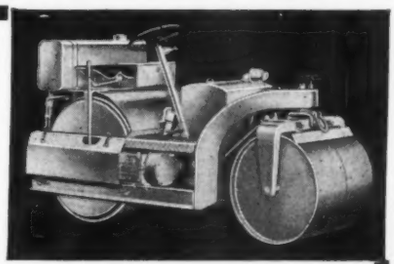

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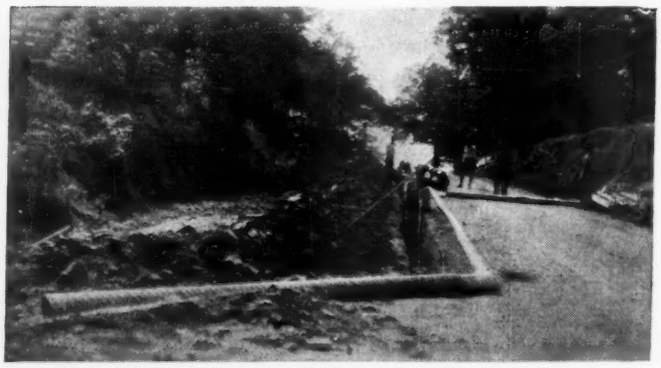

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Tar Surfacing on Steep Gradients

Roads where gradients are considerable require especially rough surfacing. An account is given of the construction of a road in the Homburg, Germany, (Saar) district, where the gradients occasionally reach 1 in 6. An 8-in. foundation of stone pitching was covered with macadam into which sand was rolled. The surfacing was of the "Einstreudecke" type; tarred stone chippings 0.6 in. to dust were rolled into the macadam at the rate of 55 lb./sq. yd., while a similar quantity of chippings served both as a sealing coat and as a binder course to receive the non-skid surface layer. This was applied in two stages. Tarred gravel, 0.6 in. to dust, was applied at the rate of 46 lb./sq. yd. and carefully shaped, and coarse tarred chippings, 0.8 to 1.2 in., were then applied at the rate of 46 to 55 lb./sq. yd. and rolled in.

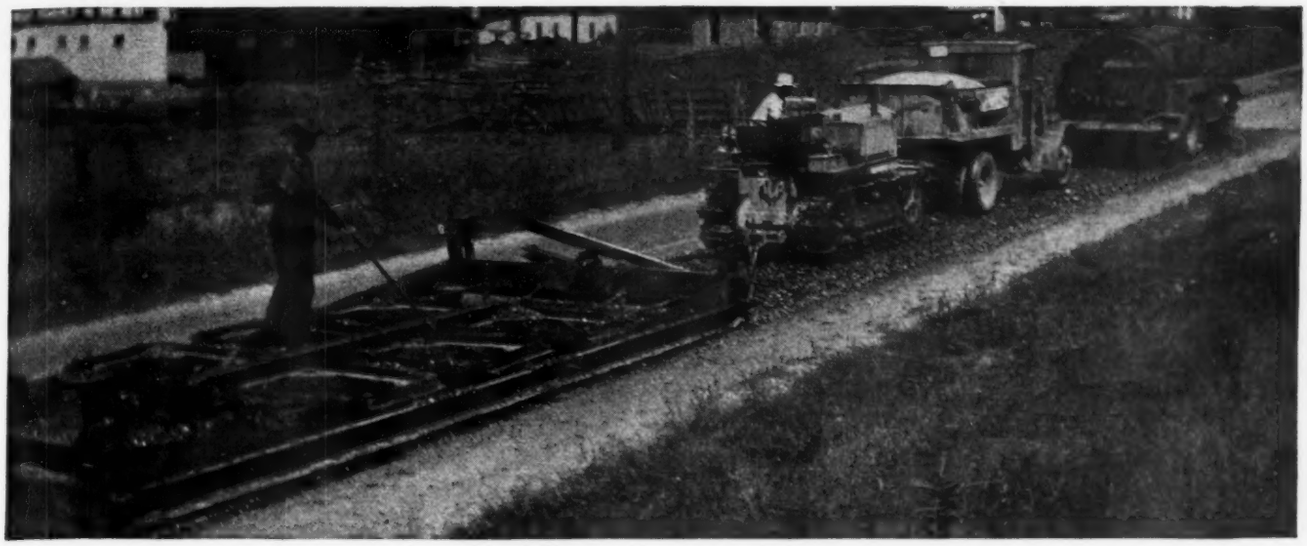
The coarser material penetrated into the finer and formed a satisfactory bond. Although the surface was sufficiently rough for use on steep gradients the texture was so close as to render surface treatment unnecessary. On gradients of 1 in 50 to 1 in 16 tarred chippings, 0.6 in. of dust, were used instead of the coarse chippings. As the road is used mainly by motor traffic, and will therefore not undergo appreciable consolidation under traffic, fine chippings were applied over the coarse chippings in certain exposed situations.

Similar surfacings have been constructed elsewhere for use on gradients of 1 in 12 and 1 in 10, macadam being substituted for fine chippings and chippings for the mineral filler used in the foundation. In the Höllental Road in the Black Forest a coarse tar-concrete was used. The coarsest aggregate consisted of stone chippings, 0.6 to 0.72 in. The surfacing has a close texture, but the surface is non-skid, and the riding quality is said to be excellent. On the western slope of the Gross Glockner Road "Wetterteer" has been used successfully. The tar is applied to limestone macadam in two stages and covered with coarse chippings. A sealing coat has not been necessary. A rough surface can be produced on the "Einstreudecke" if the tarred chippings are used in sufficient quantity to fill the interstices completely without covering the surface of the stone. A case is described in which tarred chippings at the rate of 92 lb./sq. yd. were rolled into macadam applied at the rate of 230 lb./sq. yd. No surface tarring was required until the following autumn, after which the non-skid character of the surface was restored by applying basalt chippings 0.2 to 0.6 in. *Road Abstracts.*

Action for Lumber Used on Highways

Action was brought for the price of lumber delivered to a town and used on highways and a bridge. The defense was that the person ordering the lumber had no authority from the town to do so, and that a municipal corporation is bound only by the acts of its agents within the scope of their authority. The lumber was ordered by an engineer connected with the State Highway Department. The work on which it was used was done under the supervision of an advisory committee of the town. The Rhode Island Supreme Court held (Contu Lumber Co. v. Coffin,* 194 Atl. 715) that the person ordering the lumber acted on behalf of the advisory committee's engineer, the order was, in effect, that of the committee, and that the town became liable for the bill. The fact that the lumber was used on a relief project in which the state and federal governments were involved was held immaterial.

*Coffin was town treasurer of the Town of Johnston.



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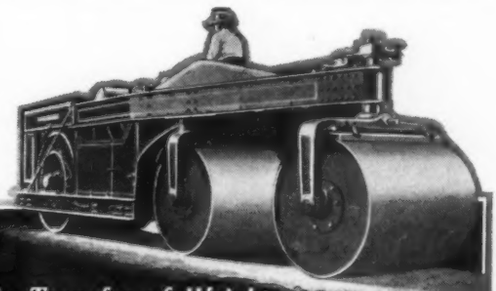

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For descriptions of helpful booklets and catalogs, see pages 79-81.

Following is a digest of the important articles published last month having to do with water works design, construction and operation and water purification, arranged in easy reference form.

The Water Wheel

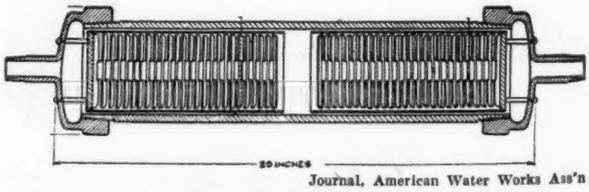
Concrete-lined steel pipe 48″ inside diameter was laid for the city of Toronto, Ont. for a length of 7½ miles, being lined in the shops of the Dominion Bridge Co. and covered with concrete in the trench. The pipe is shop-welded in 30 ft. sections. Wire mesh reinforcing is attached by clips to hoops which are tack welded to the inside of the pipe, and concrete (minimum strength 7,000 lb. in 28 days) is placed while the tube is rotating with a peripheral velocity of about 700 ft. per min. When enough has been placed to give a 1½″ lining the speed of rotation is increased to 2500 ft. and maintained until 70% of the mixing water has been driven off and the concrete sufficiently set to remain in place. It is then moist cured for 10 days. Elbows and other specials are not rotated, but the concrete is applied with a cement gun and trowel-finished by hand.[M4]

Ottawa also laid 2200 ft. of 48″ steel pipe, lined and surounded with concrete; 619 ft. being supported on a steel bridge across a part of the Ottawa river. The concrete lining was spun on 1¼″ thick, reinforced with twenty ¼″ longitudinal rods and a spiral of ¼″ rods with a uniform pitch of four inches. The external covering was placed with vibrators, reinforced with twenty ⅜″ longitudinal rods and a spiral of ½″ rods with a pitch of 2⅝″; the spiral steel both inside and out being set with ⅜″ clearance from the steel cylinder. The pipe was laid with 7 Dresser couplings for expansion joints and the rest with leaded bell and spigot joints. The 619 ft. exposed on the bridge was *protected from freezing* as follows: A 1¼″ steam pipe was fastened to each side of the main, and their outer sides covered with a half-section of asbestos insulation. Then a layer of expanded metal was wrapped around the main, providing an air space between it and the insulation, which consisted of two layers of rock cork strapped in place and covered with a ½″ wire mesh to which was applied ¼″ thickness of asbestos cement felting and over this ¼″ of plastic asbestos asphalt weatherproofing finished with a trowel.[M3]

Cleaning filters with sulphur dioxide has been demonstrated successfully at Baltimore, Batavia and Valley Stream, N. Y., after having been developed at the plant of the West Va. Pulp & Paper Co. SO_2 was introduced into the filter outlet and enough wash water supplied to give a 2% solution and fill the bed, and allowed to stand several hours, drained off, and the filter backwashed. Frequent weak solutions are preferable to one strong one. Advantages claimed: SO_2 easily obtained at reasonable cost. Application simple; labor required, one man for a few hours; the SO_2 removes manganese and iron, kills bacteria and plankton, disintegrates mud balls, opens closed ports in collector pipes; is less dangerous to handle than sulphuric acid, sodium hydroxide and many other aggressive chemicals; removal of sand is unnecessary.[G7]

Cement lining cast iron pipe removed from a wartime overbuilt distribution system at Nitro, W. Va., cost (including excavating, cleaning, handling, etc.) from 18.5% (for 24″ pipe) to 34.7% (for 4″ pipe) as much as new cement-lined pipe. Removing and stacking in yard cost 18.6 cts. for 4″ pipe to $1.042 for 24″. Cleaning, cement-lining and painting cost: For 4″ pipe, 5.27 cts. for payroll, 0.949 ct. for cement, .145 ct. for sand, .56 ct. for paint, .274 ct. for gas and .567 ct. miscellaneous, total 7.765 cts. For 24″ pipe, 21.1 cts. for payroll, 13.009 cts. for cement, 4.46 cts. for sand, 2.265 cts. for paint, 1.564 cts. for gas, 3.660 cts. miscellaneous and 10.520 cts. hauling, total 56.518 cts. In cleaning the pipe, mud was washed from interior and exterior with high-pressure water streams, pipe heated with gasjet torches, washed again, the pipe rolled onto revolving pulleys and rotated about 300 ft. per min. with a heavy iron bar inside to break tubercels, brushed with heavy wire brushes on a pole until smooth, cleaned with compressed air. Concrete, 2 cement to 1 sand, is deposited in pipe from a trough, then the pipe is rotated at 550 to 600 ft. per min. until mortar surface is smooth and glistening. Ends of pipe are then covered with tar paper to retain moisture for 7 days, and pipe is painted on the outside.[G8]

Water hammer relief is obtained by closing valves slowly, by spring-operated relief valves, surge tanks, automatic hydraulic or electric surge suppressors, mechanical shock absorbers or cushions, or air chambers. When it functions, an air chamber is the most economical and efficient device for distribution systems of buildings, but loses its air in use. The University of Wisconsin has developed a mechanical-pneumatic fluid impact absorber or arrester and tested it on ½″ to 2″ pipes up to 400′ long. It consists of an expansion chamber similar in shape to an air chamber, in which is a compression chamber constructed of fluted spring tempered bronze resilient discs forming a type of bellows construction, filled partly with water and partly with air or gas under atmospheric pressure and sealed. The expansion chamber is connected to the pipe, and the water pressure compresses the air in the compression chamber, shortening the bellows so it occupies less space in the expansion chamber. There is no tendency to eject the water, for the pressure in the compression chamber always equals that in the surrounding expansion chamber. The optimum size of compression chamber for a given case can be taken from a table, depending on the length and size pipe in the system, and the velocity of flow which causes the water hammer. One containing 13 cu. ft. of air is recommended for 10 ft. velocity and 100 ft. of ¾″ pipe; one with 134 cu. ft. of air for 350 ft. of 1″ pipe or 150 ft. of 2″ pipe; air volumes being measured at atmospheric pressure.[A34]



Journal, American Water Works Ass'n

Fifty-Flange bellows of mechanical-pneumatic fluid impact absorber

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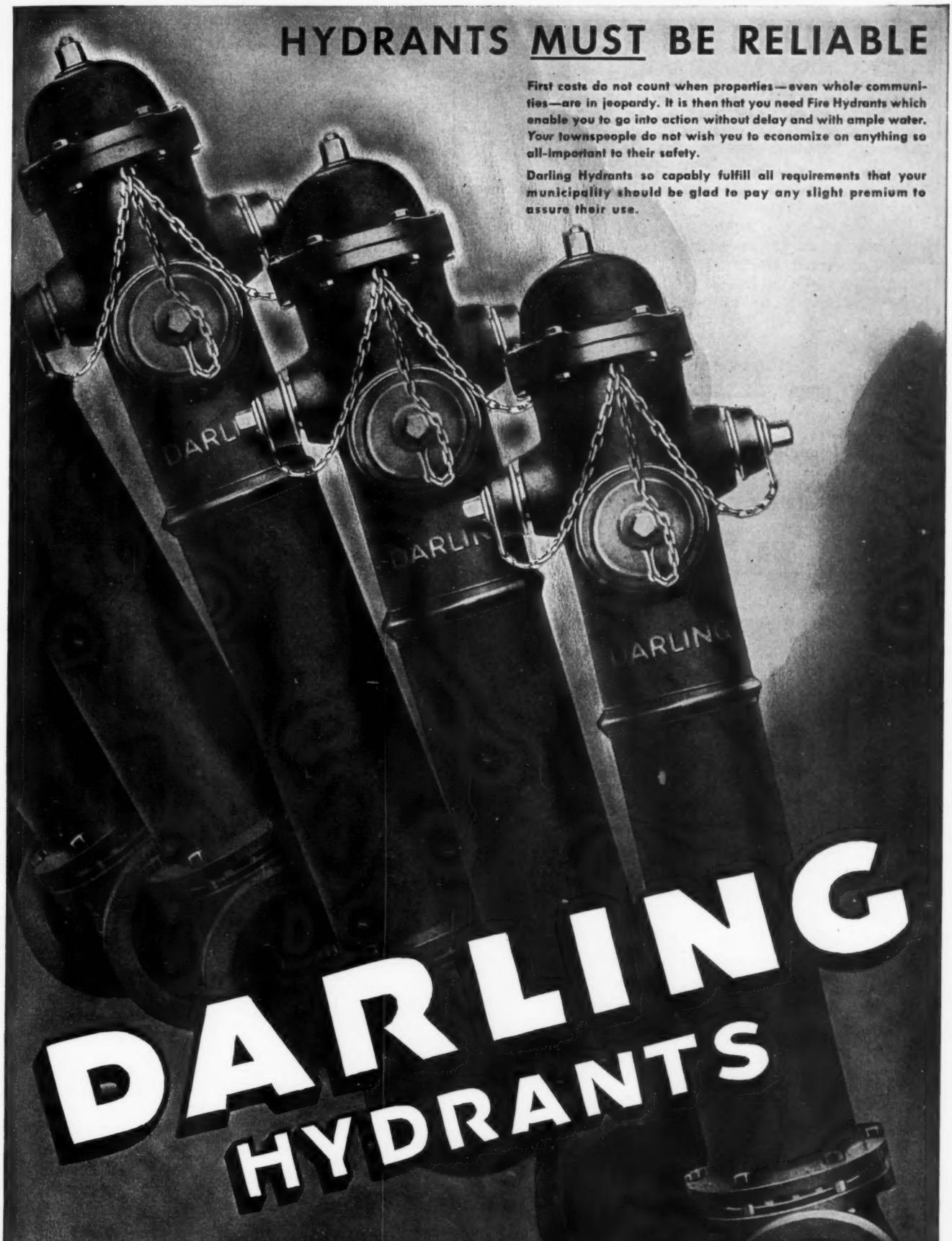

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Flexible joints in cast-iron pipe, "metropolitan" type, were tested by the Baltimore bureau of water supply to learn the effect of a pull of 15 tons in drawing the pipe across a stream after jointing on land. The spigot end was greased and the joint then poured with virgin lead and caulked. The pull was made by internal hydraulic pressure, and the motion at the joint measured. Up to 25 tons there was no appreciable movement, but then a 3/64 inch movement occurred; from then on movement increased with increased pressure and the joint pulled apart at 100 tons. At 10 tons the joint weeped at one point; at 20 tons there was slight leakage; but at 35 tons and beyond there was no leakage.[E8]

Magno-doublesalt is a new medium for neutralization of corrosive action made by roasting dolomite, driving the CO_2 off from the magnesium but leaving it in combination with the calcium. In reacting with water containing CO_2, one atom of magnesium in the doublesalt combines with 2 molecules of CO_2 whereas one atom of calcium combines with only one molecule of CO_2. It may be used in an ordinary rapid filter, being replenished as it is consumed. Hot water can be circulated through it and proper equilibrium established. It can be used for deferrization and demanganization in combination with neutralization. Quantity usually provided is 7,000 to 9,000 lb. of this material per mgd capacity; loss is 10.8 lb. per mg for each ppm of CO_2. Protection is carried to the dead end of the distribution system. The material is made in Germany and not yet available in this country, but the makers announce their intention of making it here.[B5]

Cast-iron pipe specifications of the American Water Works Assn., just receiving final approval, "cover all procedure in laying, testing and chlorinating a system of bell-and-spigot cast-iron pipe for water works; the furnishing of sheeting, blocking, backing, joint materials and sterilizing agents"; but not any other kind of pipe or type of joint. Among the comparatively new features included are sterilizing yarning materials; jointing with sulphur compounds or portland cement; testing lines jointed with these materials; chlorinating pipe lines with either liquid chlorine direct or in solution, or calcium hypochlorite or chlorinated lime either dry or water mixture.[A48]

Copper service pipe is used in Manasquam, N. J., with its sandy soil, and soft water, pH of 5.3 and iron content. Crenothrix, which clogs iron and lead pipe, gives much less trouble in copper, probably because the copper exerts a poisonous effect on algae. In installing a service, one end of the copper pipe is attached to the corporation, which is then opened and the other end pushed through the sandy soil, which the water washes out ahead for a distance up to 20 ft. In replacing iron services with copper, the latter is fastened to one end of the old iron service, which is then pulled out drawing the copper pipe after it, the iron pipe being cut off a few feet at a time as it emerges from the ground.[G12]

Removal of iron from water containing free carbon dioxide is best effected by the contact-type filters. Success depends mainly on selection of the proper degree of preliminary aeration, determined by the comparative carbonate hardness. Operation is limited to filter washing, down-washing once a week and pressure up-wash once a month. The higher the iron content of the raw water, the more complete the iron removal. Iron con-

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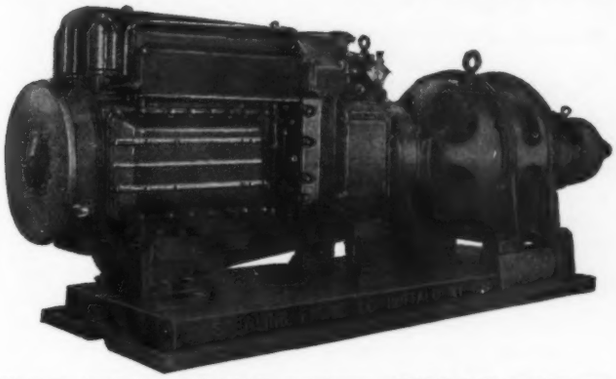

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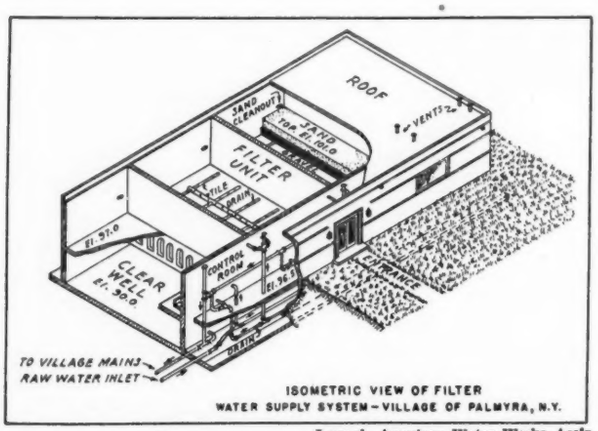
tents up to 15 to 20 ppm are reduced continuously to 0.05 ppm and even 0.02 ppm. It is recommended that the plant construction be such that no iron is in contact with the water between preliminary and final aeration. The final aeration should be as complete as possible, especially with a water running low in carbonate alkalinity.[B11]

Mineral salts as found in water supplies rarely have any effect on public health. Copper up to 0.2 ppm is probably helpful. The time may come when it will be considered by health authorities to be advantageous biochemically to have traces of copper in public water supplies; 1 ppm would be safe. Aluminum ions constitute no public health problem. Arsenic at rate of 0.2 ppm has never proven harmful. Treasury Dept. standards for caustic alkalinity are unnecessary — calcium and magnesium ions are of no public health concern. "As a general rule, except for a very few of the ions such as lead and fluorine, the taste factor will prevent consumers from harming themselves physiologically from water ingested. . . . The copper, caustic alkalinity and zinc limits in Appendix IV, U. S. Public Health Service Water Standards, should be made less strict. It is judicious to maintain the lead limit so as to be on the safe side. Limits for fluorides should be added and, rather remotely perhaps, limits for barium and selenium."[A49]

A **slow sand filter,** 320,000 gpd capacity, was built by Palmyra, N. Y., instead of the usual rapid sand because the difference in cost was estimated to be negligible and "the operating cost of the rapid sand filter, which entailed both power and labor, made the decision in favor of the slow sand filter." There are four 80 gpd units at 5 mgd per acre, with 6″ and 3″ tile underdrains, under 18″ of graded gravel, on which is 3 ft. of filter sand of 0.26 mm effective size and 2.0 uniformity coefficient. The filters are built above ground in a concrete building with a concrete deck roof. During the 18 months since the plant was built the filter sand has not been cleaned or touched and the loss of head is negligible. The filter plant cost $29,377.[A52]

A **rapid sand filter,** 200,000 gpd, for Cayuga, N. Y., cost $14,000, including several automatic features. It includes an Aer-O-Mix aerator in a basin of 20 min. capacity, sedimentation basin giving 3 to 4 hrs. detention, two 70 gpm filter units (only one equipped at first), and a 22,000 gal. clear water well. For washing the filters, a 400 gpm pump costing $300 was adopted as more economical than an overhead tank with a water level control valve fed from the high-lift pumps. For priming the service pumps, choice was made between setting them so low that the suctions would always be flooded, or providing an automatic priming system, or a priming tank for each pump. The last was cheapest and was selected. Operation of the high-lift pump is controlled by the level of water in the standpipe; while a level controller prevents it from emptying the clear well and also the low-lift pump from flooding the clear well, and stops and starts the chemical feeders as necessary. Also an hydraulic valve on the filter outlet closes automatically when the low-lift pump stops.[A51]



Journal, American Water Works Ass'n

Slow sand filter at Palmyra, N. Y.

Bibliography of Recent Waterworks Literature

The articles in each magazine are numbered continuously throughout the year, beginning with our January issue.

c. Indicates construction article; *n*, note or short article; *p*, paper before a society (complete or abstract); *t*, technical article.

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50. Treatment of Natural Waters to Prevent and Control Corrosion. By C. W. Borgman. Pp. 265-272.
51. The Cayuga Filter Plant. By C. E. Elmendorf. Pp. 273-279.
52. The Palmyra Filter Plant. By A. B. Squire. Pp. 280-288.
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54. The Present Condition of New York City's Long Island Sources of Water Supply. By W. F. Laase. Pp. 298-301.
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W *Johnson National Drillers Journal*
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1. Air Conditioning with Well Water. Pp. 1-7, 13-15.

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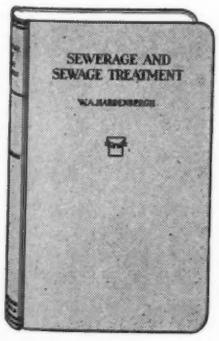

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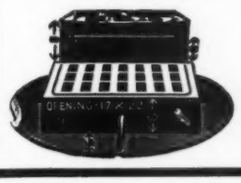

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A Digest of the Sewerage Literature of the Month giving the main features of all the important articles published

The Digestion Tank

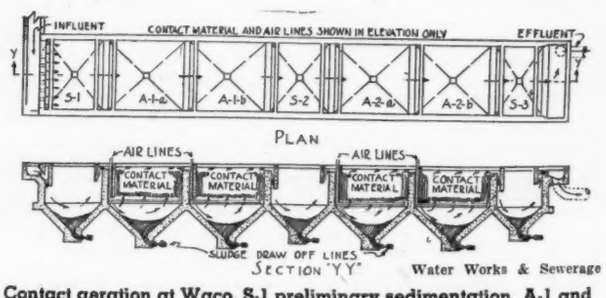
Grease removal by aeration is more than doubled by the addition of chlorine to the air, according to tests at Baltimore. With the application of 1 ppm of chlorine and only 5 min. aeration the yield of scum was doubled; 5 ppm gave maximum results; 5 min. aeration gave generally as good results as 15. Air was applied at the rate of approximately .012 cu. ft. per gal. per min. through "Aloxite" tubes in the tank bottom. "At plants where grease is separated from sewage by aeration, a large amount of additional material can be removed by the injection of chlorine into the air supply. The feature of particular interest is that such a small amount of chlorine gives so considerable an increase in yield. . . . A further investigation of this problem may indicate that when chlorine is used even less air may be required to accomplish the same results. And, in addition to increased efficiency, the combined cost of chlorine and air may be actually less than when using a larger volume of air."[G13]

Tannery wastes from Pennsylvania plants are generally treated under a procedure developed by the State Health Dept. as follows: Mixture of all the tannery wastes, sedimentation, and discharge of settled liquid at a uniform rate during the 24 hrs. In addition, where necessary, spent tanning liquor is collected separately and stored during months of low stream flow, to be discharged later during high water. If secondary treatment of settled waste is necessary, trickling filters will be used (none used in the state so far). Mixture and sedimentation are obtained in tanks of 8-hr. nominal detention period without special mixing equipment, followed by secondary tanks of variable level type of 16 hr. capacity, float-supported outlet pipes discharging through swinging drawn-down pipes arranged to give uniform flow throughout the 24 hrs. Sludge is dried on beds with 1 sq. ft. per lb. of hides processed per day, removed at 80% moisture. The wet sludge is piped to storage lagoons, dried for a period of years, and then removed by power shovel and trucks to dump.[J8]

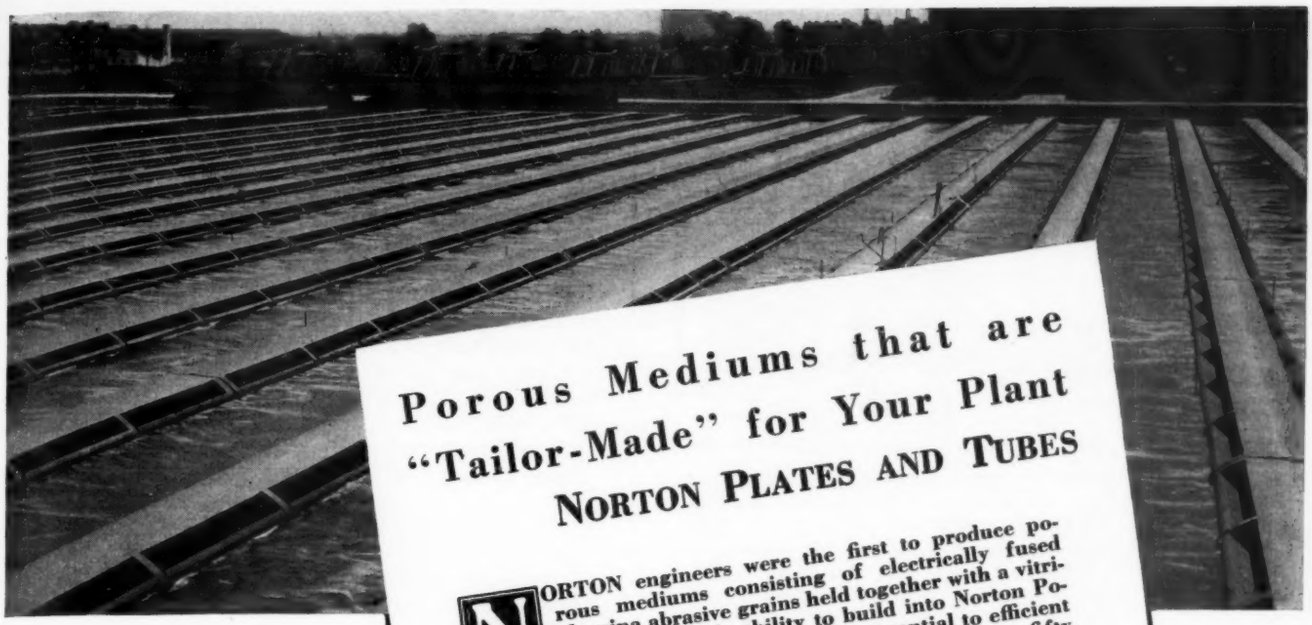
The **viscous flow** properties of sewage sludge have been studied by W. D. Hatfield, using a rotational viscometer. He concludes that these properties are pseudo-plastic; i.e. the apparent viscosity decreases as the rate of shear and the shearing stress increase. The sludge is thixotropic, the pseudo-plastic resistance and therefore the apparent viscosity being greatly reduced by stirring or shaking, suggesting certain practical applications in the pumping of thick sludges and in increased convection velocities past submerged heating coils in heated digestion tanks. The apparent viscosity when plotted against the rate of flow or the per cent solids produces a straight line on logarithmic coordinates. Application of the laws of fluid flow to sewage sludge gives valuable information even though these laws are only an approximation when applied to pseudo-plastic flow.[C16]

Sludge digestion tank construction at Buffalo was facilitated by special equipment for the circular sloping bottom—a rotating truss screed that struck off the bottom slab concrete to the correct pitch and thickness, and a whirligig chute arrangement for depositing concrete in the high circular walls in even spiral courses.[E8]

Contact aeration to produce bio-flocculation is being tried experimentally at Waco and Bryan, Texas, the sewage being passed through contact material in tanks after first being aerated. When raw sewage was used, solids accumulated so rapidly on the contacts materials and sloughed off so quickly that there was little oxidation, so settled sewage was used. This was passed through several tanks in series; at Waco, there are 2 contact tanks, an open settling tank, 2 contact tanks and a final settling tank. Each contact tank contains, below the contact material, a pipe grid through which air is applied. Sewage enters at the bottom, passes up through the contact material and out over a weir. Part of the deposited solids, when they separate from the surfaces, settle to a bottom hopper and part are carried over to the next tank. The zoological jelly in the first two tanks is heavy, gray in color and abounding in beggiatoa. In the last tanks the jelly is thin and transparent and contains clear-water organisms and no beggiatoa, and dissolved oxygen and nitrates begin to appear. The amount of air used varied from 1.25 to 1.8 cu. ft. per gal. at a pressure of 2.6 lb. at the compressor. The effluent was compared with that from the city's activated sludge plant, and the two showed: oxidized nitrogen, 16.2 ppm and 11.8 respectively; dissolved oxygen, 4.7 and 3.9; B.O.D., 14.1 and 24.9 (reduced from 108.6); suspended solids 17.0 and 21.3 (reduced from 111.0). Thus the reduction of B.O.D. was 87% by contact aeration and 77% by activated sludge. The time the sewage spent in the tanks was: first two tanks, 45 min.; 3rd (sedimentation), 30 min.; next two tanks, 1 hr. 40 min.; final sedimentation, 10 min. Operating so that time in the first two tanks was 1.25 hr. and in the last two contacts 45 min., free ammonia was reduced to 3.8 ppm, B.O.D. to 7.2 and suspended solids to 5.3, with 4.6 ppm dissolved oxygen. As contact materials, 2" to 3" crushed stone, 3" concrete cylinders stacked on 3" centers, and corrugated aluminum plates placed vertically 1" apart, were used. Laths seemed undesirable. Aluminum plates give 92% void space; thin film in last tanks does not adhere well to it. This type of plant is not subject to upsets, is flexible in design, adaptable to any desired degree of purification, capacity is easily increased, no loss of head, low air pressure.[G14]



Contact aeration at Waco, S-1 preliminary sedimentation, A-1 and A-2—contact tanks. S-3 final settling tank.



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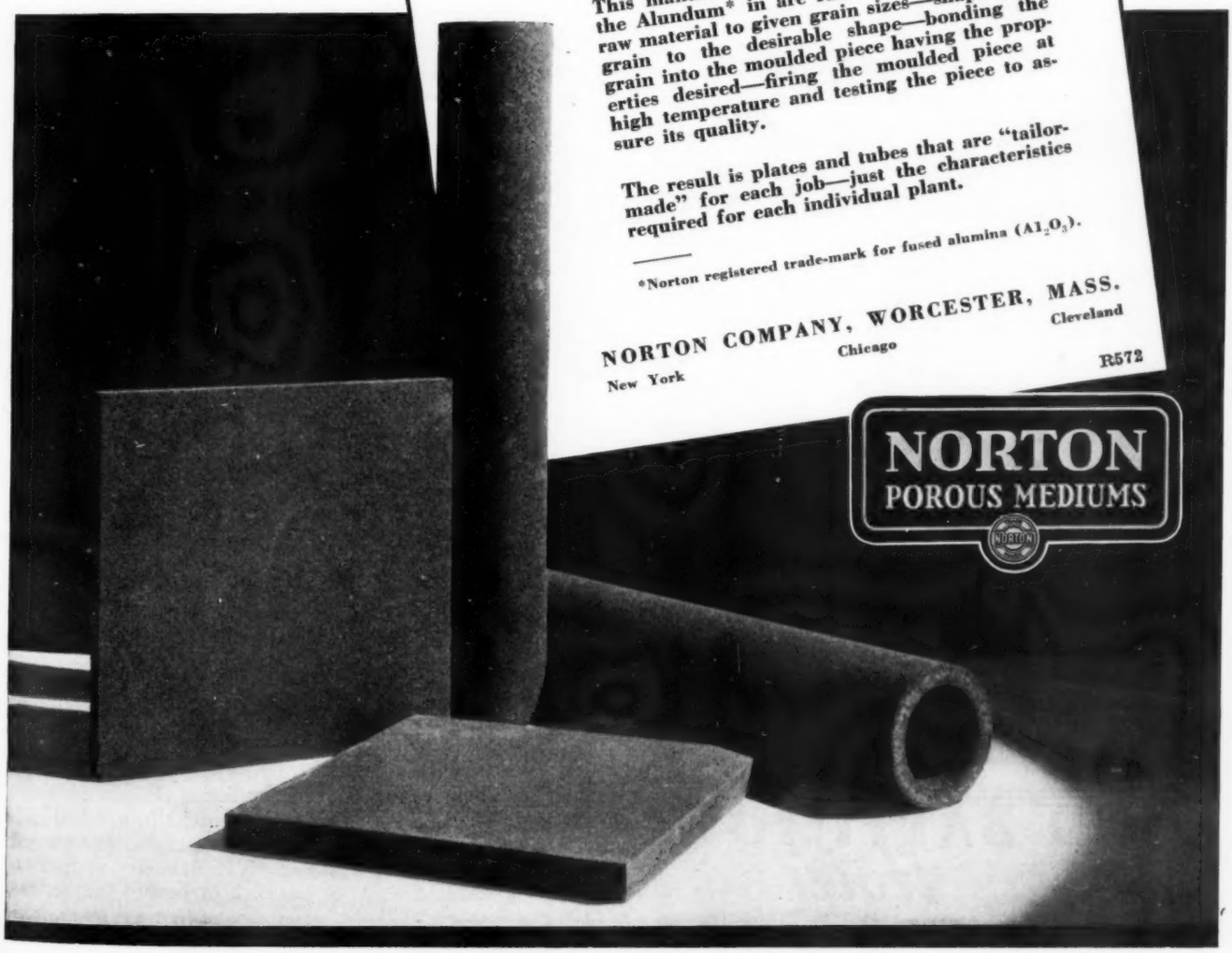

For descriptions of helpful booklets and catalogs, see pages 79-81.

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Continuous pH recorders have established their value in England. They enable effluents from industrial processes to be rendered harmless; provide a watchful record on the nature of incoming sewage; the bacteriological processes can be adjusted to maintain maximum activity; sedimentation can be improved and so increase filter capacity; grease and colloids can be removed with economy of chemicals; and it provides illuminating data on experimental processes.[D24]

Equipment unusual, at least in New Jersey, has been installed recently in the Raritan, Rahway and Elizabeth river valleys as follows: rectangular tank sludge-scraping mechanism (Mieder) at Elizabeth. Picket-fence type of thickening device (first in the East) at Elizabeth. Two-stage digestion tanks at Rahway Valley Joint Meeting and Bound Brook plants; grinding digested sludge at the former. Multiple-hearth incinerator for screenings, sludge and garbage at Raritan. Mechanically cleaned sand strainers at Raritan, Somerville, South River and Sayreville; and automatically cleaned magnetic strainers at Perth Amboy. Rotary trickling filter distributors and "Transite" plant piping at Manville. Rapid mixers and flocculators, vacuum dewatering of digested sludge, and panel-type chlorinators at New Brunswick. Screenings shredder at Highland Park. Flocculation by air diffusion at South River and Sayreville. The South River plant, with a capacity of only 750,000 gpd, contains 28 motors, mostly small. The 15 recent plants vary in capacity from 100 mgd (Elizabeth Valley) to 0.6 mgd (Raritan Township). The costs, averaged by sizes, were: 0.6-1.2 mgd, $140,-600 per mg design capacity; 1.9-2.0 mgd, $74,600; 9-10 mgd, $37,000; 25 mgd, $20,000; 100 mgd, $11,900 (not including sewers, booster stations, land, etc.).[G15]

Garbage-sludge mixtures digested or garbage mixed with settled fresh sewage solids yield filter cakes with practically the same moisture content as sludge alone, when the same quantities of chemicals are added to the same solids concentrations. No apparent differences of dewatering, difficulties in drying, or nuisances of digested sludge-garbage mixtures were found as compared with digested sewage solids. With fresh sewage solids increased by an equal amount of ground garbage solids, the sludge volume is doubled, the cost for chemicals increased 1.5 to 2 times. The ease of dewatering the digested mixtures appears to depend on the same factors as for digested sewage alone. Ground garbage should not be added directly to fresh sludge before dewatering, but to the sewage before it enters the settling tank, to permit soluble and finely divided garbage solids to pass out; and the same holds for digested sludge when garbage is added at the time of dewatering.[H33]

Sewage straining through a magnetite filter in a settling tank at Goshen, Ind., produced an effluent whose suspended solids content increased little with large increases in raw sewage solids. The total removals averaged 61% to 63% of suspended solids and 46% to 48% of the B.O.D., of which totals 50% of suspended solids and 33% of B.O.D. was removed by sedimentation and the balance by the magnetite filter; or the latter removed 23% of the suspended matter and B.O.D. reaching it.[H35]

Sludge digestion has been studied at Gravesend, England, where the sludge is first heated in a 7,500 gal. chamber by means of cast iron radiators, then passed into two digestion tanks of 43 ft. diameter and 45 ft. deep, used in series or parallel, or heated sludge was run into one tank and cold sludge into the other. The sewage was domestic and very strong (water consump-

tion 18 gpd per capita) with B.O.D. over 800. Sludge was introduced twice a day. During 4½ yrs. operation no scum has formed. High rate of gas formation causes vigorous circulation, and it has never been possible to withdraw supernatant, the sludge being of the same consistency from top to bottom of tank. If the sludge be placed in a shallow tank, very good separation of clear liquid and sludge is obtained in 4 to 5 hrs. In two-stage digestion with only the first tank heated, the main reaction in the primary tank was fermentation with almost complete conversion to gas, but the secondary tank gave almost complete liquefaction with very little conversion to gas. With the secondary tank kept warmer than the primary there was both liquefaction and gasification in the primary tank, and almost wholly liquefaction in the secondary. With single-stage digestion, only one tank heated, both tanks gave gasification with some liquefaction, but the cooler tank gave more liquefaction than the warmer. Single-stage digestion gave poorer results than two-stage, regardless of heat variations. The cast iron radiators with their rough surfaces had inappreciable effect in heating the sludge but 1½" smooth iron pipes substituted for them were quite successful.[D28]

Cleaning sewers in Los Angeles, Calif., has been greatly reduced by continuous, routine inspection, each manhole inspected every 6 mo., or 3 mo. where conditions are bad. Ten years ago there were 1,253 stoppages in 1,989 miles of sewer; now, with 3,000 miles, the stoppages are below 100. With hand labor, a crew of 4 men usually could not rod more than 800 to 1,000 ft. a day; nearly twice this length can be cleaned by 3 men using a power-operated spring-steel rod pulled back and forth with various tools attached.[E9]

Bibliography of Recent Sewerage Literature

The articles in each magazine are numbered continuously throughout the year, beginning with our January issue.

c. Indicates construction article; *n*, note or short article; *p*, paper before a society (complete or abstract); *t*, technical article.

D *The Surveyor*

February 25

24. *p.* Determination of Hydrogen Ion Concentration. By R. S. Medlock. Pp. 347-349.

March 4

25. *p.* Reconditioning of Old Sewage Works. By G. M. C. Taylor. Pp. 361-362.
26. *p.* Experimental Rapid Filtration at Huddersfield. By H. H. Goldthorpe. Pp. 365-366.
27. *p.* Sea Outfall Sewers. By G. M. C. Taylor. P. 366 c.

March 11

28. *p.* Studies in Sludge Digestion. By R. Hicks. P. 383.
29. Rapid Filtration of Sewage. Discussion of D26. Pp. 385-388.

E *Engineering News-Record*

March 3

7. *p.* How to Specify Disposal Equipment. By C. J. Velz. P. 329.
8. *c.* Special Rigs Speed Concreting on Circular Sewage Tanks. P. 338.

March 10

9. Sewer Stoppages Cut 90 Percent. P. 370.

G *Water Works and Sewerage*

March

14. Bio-Flocculation and Contact Aeration. By E. W. Steel. Pp. 158-161.
15. *p.* New Jersey's Progress in Alleviating Stream Pollution. By W. Rudolfs. Pp. 165-171.
16. Main Drainage of London. By J. D. Watson. Pp. 179-181.
17. *p.* Random Thoughts on Sewage Disposal. By V. Greiff. Pp. 189-190.

H *Municipal Sanitation*

March

33. Effect of Garbage Upon the Dewatering of Sludge. By W. Rudolfs and R. S. Ingols. Pp. 172-174.
34. Packing Waste Plant Pays Its Way. By J. A. Carollo. Pp. 175-176.
35. Goshen Mechanically Strains Its Settled Sewage. By E. Hurwitz and M. J. Miller. Pp. 177-179.
36. Incineration of Municipal Refuse: The Furnace. By H. W. Taylor. Pp. 187-189.

J *American City*

March

12. Sewage Treatment Projects on Lower Fox River, Wis. By S. A. Greeley. Pp. 37-40.
13. Incinerators for Garbage and Refuse Disposal. By H. S. Hersey. Pp. 85, 87, 89.

P *Public Works*

March

13. Gas Production and Utilization at the Wichita Treatment Plant. By P. L. Brockway. Pp. 11-13.
14. New Disposal Plant from Old Septic Tank. By G. M. Passell. P. 32.

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Sanitation Beyond the Sewer Lines—Disposal of the Effluent

IN a recent article, the design of septic tanks for camp and home sewage disposal was discussed. Selection of the general type of treatment and determination of the tank size—also its procurement or even construction—are simple, as compared to the final disposal of the septic tank effluent.

Most of these difficulties are due to one or more of the following: (a) an insufficient area of ground is available for proper disposal; (b) topographical conditions are unfavorable, as tight soil, poor drainage, wet or swampy areas, the presence of rock, etc.; (c) an insufficient amount of money is available for the work necessary to do a good job; (d) there is lack of knowledge as to both present and future conditions.

The first two problems could more easily be overcome if the home or factory owner or camp proprietor consulted the engineer before the architect began his work. Slight variations in layout or location often reduce disproportionately the problems in waste disposal. Regarding (c), owners often are indisposed to spend enough money to do a good job, as they consider the individual septic tank installation only a temporary, or even an unsatisfactory substitute for a sewer system. There may be situations in which these are true, but a properly designed, constructed and maintained installation will give service, practically equivalent in satisfaction and cost to that furnished by a sewer system. It is probable that the most difficult problem in small plant design is to convince the owner of the needs for early consideration and for providing for long-time, trouble-free service.

The Disposal Problem

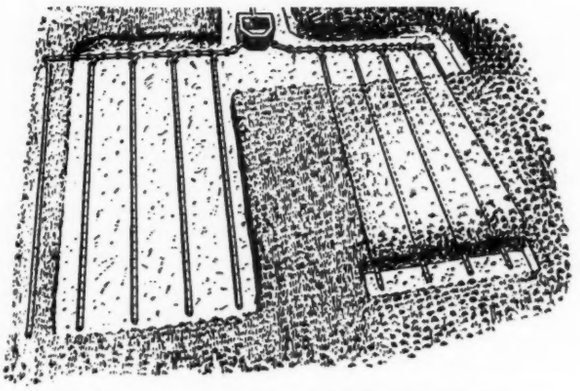
As stated in an earlier article, the small septic tank is perhaps the most satisfactory method of primary treatment. The small Imhoff tank is more costly and, under usual conditions, is no more effective.

The disposal of the overflow or effluent from the tank is the most difficult problem. In general, there are just two methods of disposal—by subsurface methods, and by some type of filters.

Subsurface disposal contemplates that the subsoil will absorb the liquid overflow from the tank. The amount of liquid that can be disposed of in this manner is limited and is affected sharply by the porosity of the soil, the depth of ground water, and the general drainage of the terrain. There are two principal methods: (a) by means of leaching cesspools; (b) through subsurface tile lines.

The filter types that have been used include the sand filter, the trickling filter, and the contact bed. Sand filters are prone to give off odors, whence a covering of a foot or more of top soil is sometimes added to prevent this. Trickling filters are excellent for larger installations: they are apt to be objected to as unsightly—which can be overcome by proper engineering; and some engineers do not use them for summer camps for the reason that time is required for "ripening." The same objections may be held against contact beds, but here, too, the objections are not entirely valid.

In this connection, it may be noted that no one of the methods discussed is entirely without objection. Subsoil disposal can be held to contaminate ground water. The effluent from any of the filter types must finally enter a water course, just as does the effluent from a sewage treatment plant. Yet no one would advocate the elimination of sewers and recourse to pit toilets.



Subsurface Tile Layout (Pacific Flush Tank Co.)

Subsurface Disposal Methods

The porosity of soil is the factor that determines primarily the ability to use subsurface methods of disposal. The New York State Department of health has adopted a test (the only one we are familiar with) that is a good measure of the ability of the soil to absorb liquids. For testing for subsurface tile lines, the procedure is as follows: A hole 1 foot square is dug to a depth of 18 ins. This is filled with water to a depth of 6 ins. and the drop of the water surface is observed. It is safer to repeat the procedure, and use as a basis the average time in minutes for the water to drop 1 inch (the average should be based on several inches of drop) on the second test after the ground has been thoroughly wet.

The above is for the design of tile lines. For cesspool design, a pit should be dug about one-half the depth of the proposed cesspool, and the test hole dug in the bottom of the pit.

The allowable rate of application of effluent per square foot of bottom area of trenches for disposal lines and of percolating area of cesspools is:

Time for water to drop 1 inch	Rate, gallons per sq. ft. per day	
	Trench	Cesspool
1	4.0	5.3
2	3.2	4.3
5	2.4	3.2
10	1.7	2.3
30	0.8	1.1
60	0.6	0.8

Trenches for subsurface disposal lines should ordinarily be 12 to 15 ins. wide and about 18 ins. deep. The line should be of porous or open joint tile or other material that gives good distribution, and this should be surrounded by broken stone or gravel, 6 to 18 ins. deep below the tile, and at least 4 ins. over it. The use of a siphon is desirable. A very important factor is the

grade or fall of the line. This should be not less than 3 nor more than 5 ins. in 100 ft. Single lines or runs should not exceed 150 ft. in length and parallel lines should be at least 6 ft. apart.

Applying the New York test to a soil in which it took 40 minutes for the water in the test pit to drop 4 ins., and with a trench 15 ins. wide, a line 150 ft. long would handle 1.7x1.25x150=319 gallons per day.

Cesspools are usually walled up loosely, the bottom being left open and the top domed or otherwise safely covered. A depth of 10 feet, with an effective depth of 6 or 7 ft., and diameter of 10 feet is about the maximum for the average cesspool. On the above basis of 1-inch drop of the water in the test pit in 10 minutes, a 10-ft. diameter cesspool with an effective depth of 7 ft., will care for 2.3x(78.5+220)=685 gallons per day. Excavation for the trench described in the previous paragraph will be 1.25x1.5x150=281 cu. ft. or 281÷319=.88 cu. ft. of excavation per gallon of capacity; and for the cesspool, excavation will amount to 5x5x3.1416x10=785 cu. ft., or 785÷685=1.02 cu. ft. per gallon of capacity.

Filter Construction

The usual principles of design are employed for designing trickling filters, except that rates are usually much lower than those employed for large municipal plants. In general, the smaller the plant, the lower the designed rate should be. A rate of 150,000 gallons per day per acre per foot of depth is reasonable for the smaller plants—that is about one-half the usual rate. The minimum depth is 5 feet, and 6 ft. is better. The rotary distributor is preferable to the nozzle system of distribution because it utilizes practically all the bed area, requires less head for operation, is not so likely to cause odors, and probably requires less care in operation.

The same principles govern design of contact beds. The rate should not exceed 60,000 or 70,000 gallons per day per foot of depth per acre. Possibility of causing odor, and objections to appearance are both reduced by controlling the level so that the sewage when the bed is full does not reach to within about 6 inches of the top of the stone. Distribution is through perforated pipes beneath the surface. A depth of 3 or 4 feet is desirable; 2 or more beds should be provided.

The contact bed does not give as good an effluent as the trickling filter. Both may unload at times—the trickling filter especially. Therefore a small secondary tank may follow the filter and, since in most cases the effluent from either trickling filters or contact beds should be chlorinated, this secondary settling tank may also furnish the contact period necessary after applying the chlorine.

Sand filters may be used to treat the effluent from the contact bed, the trickling filter of the septic tank. Sand beds of the usual type, uncovered, should be designed with a capacity of 50,000 gallons per acre. At least three beds should be provided; the depth of sand should be about 3 ft. Sand should have an effective size between 0.2 and 0.5 mm. and a uniformity coefficient of not more than 3.0. The filter should be underdrained.

New York recommends a covered sand filter for camps, the rate of application for settled sewage being not more than 50,000 gallons per acre per day; depth of sand 3 ft. Underdrains are placed 6 ft. apart, and distribution lines are staggered above at the same intervals. Both drains and distributors are 4-inch, and both have open joints; the underdrains should have a slope of 6 ins. in 100 ft., and the distributors are laid practically level. The filter is covered with 8 to 12 ins. of sand or porous loam.

Safer Sewage Disposal

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Recommend the San-Equip Master Tank for disposal jobs beyond the city sewer lines. The Master Septic has several exclusive features not found in the ordinary tank—provides safer, more dependable disposal service for homes and camps.

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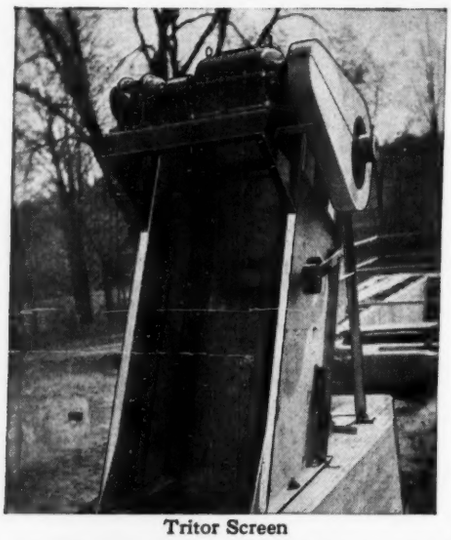

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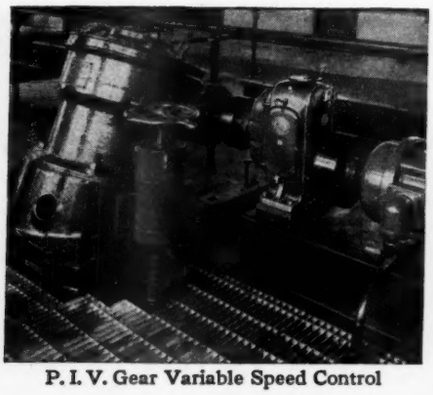

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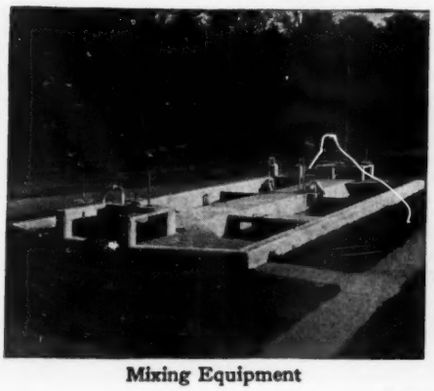

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STRAIGHTLINE Collectors

For descriptions of helpful booklets and catalogs, see pages 79-81.

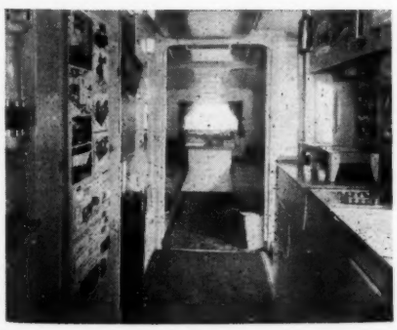
Keeping Up With New Equipment

A "Midget" Centrifugal Pump

This is getting to be quite a ladies' magazine; a couple of months ago we showed on the front cover an attractive lady inviting everyone to New Orleans. Herewith is a picture of Miss Rupp, daughter of one of the members of Gorman-Rupp, makers of centrifugal pumps. Miss Rupp is carrying the new 52-pound "Midget" pump just announced by this company; the Midget is a self-priming centrifugal which has a capacity of 5300 gallons per hour.

Miss Rupp and the "Midget" pump

Other light-weight pumps announced by Gorman-Rupp are the "Bantam," a 79-pounder that throws 7500 gph.; the "Hawk," weighing in at 103, with a capacity of 10,000 gph.; and the "Eagle," weight 118 pounds and capacity 15,000. All these ratings are at a total head of 20 feet, including 5 ft. suction lift. Suction lift 25 to 28 ft. Uses: filling tank wagons, draining ditches and sumps, dewatering barges and boats, emptying manholes and cellars, working on swimming pools, irrigation, camps, summer homes, and for water, street and sewer departments. Write Gorman-Rupp Co., Manfield, Ohio.



Interior of Jeff Corydon's new "Proportioneers" trailer, to replace the original unit which was wrecked. We trust the "hitch" on this one is better.

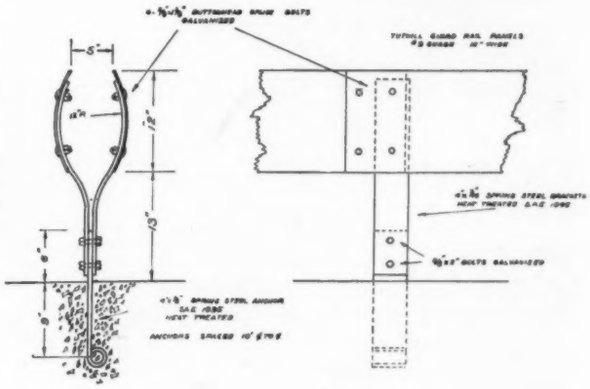
It's Easier Now to Reduce Stadia Notes

It used to be that every rainy day was spent reducing stadia notes on the good old stadia slide rule. That can be changed now; the "stadiascope" which is shown in the circular cut herewith makes it a lot easier. This is a circular chart, 24 ins. in diameter; tack it on a board; set the movable arm on the given vertical angle and read off your difference in elevation and correction for horizontal distance without further ado.

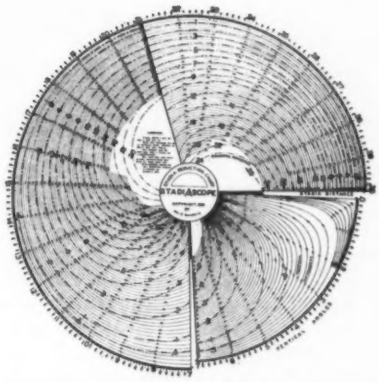
Another device by this same company is the "countourpolator" for interpolating contours from spot elevations in fast time. Both made by Engineering Devices, 763 Dawson St., New York, N. Y. Data on request.

Tank Linings for Ferric Chloride Solutions

Ferric chloride is used in some sewage treatment plants for coagulation of sewage and in others for treatment of sludge to facilitate drying; also in some water plants for coagulation. Ferric chloride is corrosive, so that proper construction and lining of tanks is necessary. In the Dearborn, Mich., plant there are five 12,000 gallon tanks that are lined with latex rubber, 3/16 inch thick; even the pipes and valves were lined. Frederick Storrer, city engineer, writes that these are in excellent condition after four years of service. The lining of these tanks was installed by Collord, Inc., Detroit, Mich., which firm has prepared data on this subject and will send it on request.



This shows how a Tuthill Guard Rail can be used to divide superhighways to prevent head-on collisions due to encroachment on opposing traffic lanes. Rail panels can be painted with black and white diagonal stripes. Takes up only small space and costs little.



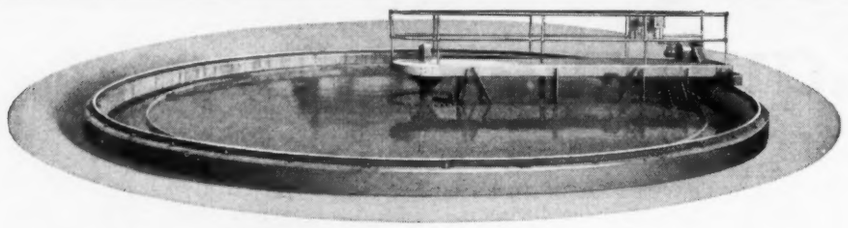
The "Stadiascope" for quickly reducing Stadia notes.

Measuring Sand Expansion

The waterworks operator ought to know how much his sand expands when he washes it. Too little expansion, and maybe he's getting mudballs; too much expansion, and he's losing sand into the wash water troughs. At last here's something that does the trick for him. No more nailing thimbles on a rod, or some other homemade gadget. A plain, readable scale indicates the expansion in percent. Often saves wash water, and helps a lot in operating a plant. Send for a copy of Bulletin 60. Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

This is the new "General" model 30 power shovel made by General Excavator Co., Marion, O.

KEEPING UP WITH NEW EQUIPMENT



Link-Belt Circuline Sludge Collector

Link-Belt Circuline Sludge Collector

A new 24-page book (No. 1642) has been issued by Link-Belt Co., 2045 Hunting Park Ave., Philadelphia, Pa., which describes their "Circuline" collector for sewage and water plant. The sludge is collected by a plow and uninterruptedly moved to the discharge sump at the center of the tank, one revolution cleaning the entire tank floor. A skimmer can be provided, which deposits the floating material into a scum box and flushes it to the desired disposal point. Sent on request.

Paving With Hydraulic Controls

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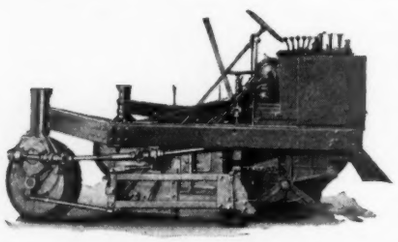


Adnun Black Top Paver

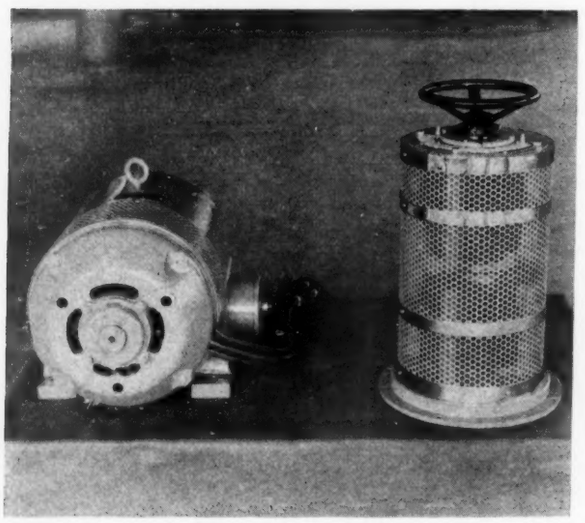
cut-off, and end gates have been replaced by hydraulic controls. The power cut-off gate at the bottom of the hopper is now divided into four sections, each section independently and hydraulically controlled by a small lever on the operating platform. This permits the opening of any section of the power cut-off to permit black top material to feed to the grade without opening any other section. Thus, the operator is in position to control shouldering or laying sections between car tracks, virtually while the machine is in motion. The screed or cutter bar can be raised at either end or both ends for super-elevated curves or crowning.

Note to Sewerage Equipment Manufacturers

The Terminology committee of the New Jersey Sewage Works Ass'n contemplates including a commercial section in their forthcoming report. All manufacturers are invited to submit definitions covering their products, especially those which play a part in sewerage and sewage treatment. The committee, of course, reserves the right to reject such definitions as they think should not be included. Definitions should be forwarded to W. C. Mallalieu, Chairman, P. O. Box 384, Boonton, N. J.

Schramm "Fordair" Compressors

The Ford V-8 engine blocks have been used as basic units for this compressor. Each outfit is a complete, self-contained air plant, with all accessory equipment. Made in three mountings—2 wheel, motor truck, and less running gear. Made in 55 and 105-ft. capacity. Excellently and fully described in the "Fordair" bulletin, which will be sent on request to Schramm, Inc., West Chester, Pa.



The Crocker - Wheeler polyspeed motors have wide range of economical speeds without rheostat losses. In other words, they will operate efficiently over a speed range of 1 to 6. Can be controlled automatically, in accordance with flow or other governing factor. Many uses in water and sewage work. For details, ask for Bulletin 251. Crocker-Wheeler Electric Mfg. Co., Ampere, N. J.

A Slick Garbage Collection Unit

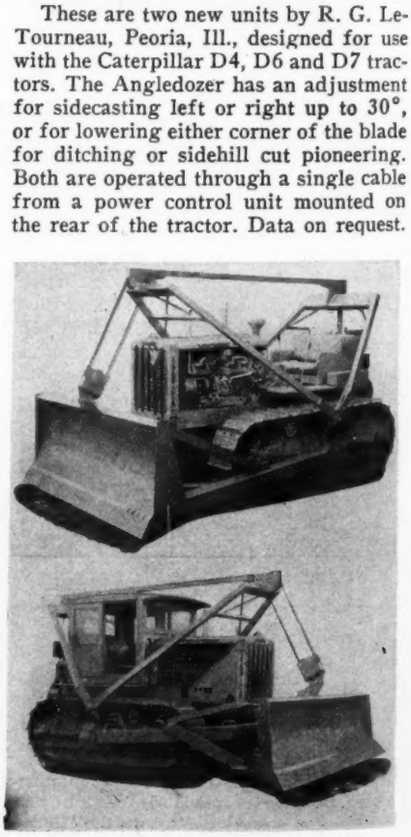
More and more interest is being shown in improving the old Model E (to use a term that will be understood by all rural sanitation workers) garbage collection bodies. This is something that is earnestly to be desired. Herewith is shown a body made by the Pneumatic Truck Body Corp., Detroit, Mich. It has a capacity of 6 cu. yds., the body is air-tight, and it eliminates the need of dumping the cans. With the 7½-inch air hose shown, this unit will empty a 20-gallon can in about 5 seconds—one sniff and that's all, so to

One sniff—and the can is empty

speak. This unit can be installed on trucks of 1½-ton capacity and larger. The hose shown was furnished by the U. S. Rubber Co., and is designed to resist fats, acids and abrasion. Fuller information from the body manufacturer.

LeTourneau Angle and Bulldozers

These are two new units by R. G. LeTourneau, Peoria, Ill., designed for use with the Caterpillar D4, D6 and D7 tractors. The Angledozer has an adjustment for sidecasting left or right up to 30°, or for lowering either corner of the blade for ditching or sidehill cut pioneering. Both are operated through a single cable from a power control unit mounted on the rear of the tractor. Data on request.



Bulldozer above and Angledozer below.

Denn M. Burgess, recently appointed domestic sales manager of R. G. Le Tourneau, Inc.

Nichols Engineering & Research Corp., 40 Wall St., N. Y., has acquired the Decarie refuse incinerator formerly manufactured by the Underpinning & Foundation Co. Messrs. Morris, Woodman, Buffington and Burgess, former engineers of the Decarie Corp., are now associated with the Nichols Corp. Sales work will be carried on under the direction of H. J. Hartley, President of Nerco, as at present with existing personnel.

Globe Phone Mfg. Co. has opened executive offices at 11 West 42nd St., N. Y. The manufacture of leak locators, pipe finders, dipping needles, pipe phone and other equipment will be continued at the Reading, Mass., factory. Plans are also under way for opening an additional plant in New York.

Norton Co., Worcester, Mass., is constructing a new 4-story building 60x333, with a floor area of 2½ acres. This is the second step in the renovation and replacement program of the Norton Co. aimed to improve working conditions and furnish employment.

Joseph S. Helm of the Standard Oil Co. of New Jersey has been elected president of the Asphalt Institute succeeding B. L. Boye. Other officers elected include James A. Blood, T. M. Martin and A. M. Maxwell, vice-presidents; Herbert Spencer, treasurer; F. V. Widger, secretary; and Mr. Boye, the above officers and David Waxman as executive committee. J. E. Pennybacker continues as managing director.

The 20th annual convention of the National Lime Association and the lime industry will be held at the Netherland Plaza Hotel, Cincinnati, Ohio, on May 9 to 11. W. V. Brumbaugh, Washington, D. C., is secretary.

SENT ON REQUEST!

"More for Your Money" is a folder by Hobart Bros., Troy, O., that tells about a new selective control that is said to cut welding costs a third to a half.

An excellent 4-page bulletin, showing the many uses of the portable wheeled roller, has been issued by Littleford Bros., Cincinnati, O. Uses include rolling patches, service cuts, widening jobs, brick pavements, retreading work, etc. Sent on request.

R. G. Le Tourneau, Inc., Peoria, Ill., has issued a new bulletin describing their 15-yard buggy for handling bigger payloads. Sent on request.

Littleford Bros., Cincinnati, O., has issued a folder listing and describing the tools you need for spring maintenance and repairing work. Sent on request. Lists 13 items of useful equipment.

Everson Mfg. Co., 214 West Huron St., Chicago, Ill., has issued a 4-page bulletin describing the Everson Rota Meter for chlorination and ammoniation. Ask for Bulletin 796.

Roots-Connersville Blower Corp., Connersville, Ind., has issued bulletin 21-B-19, which gives operating principles, volume and power curves, details of construction, accessory equipment and capacities and dimensions of blowers. Sent on request.

Allis-Chalmers, Tractor Division, Milwaukee, Wisc., has issued a 24-page booklet describing their power units; curves and technical data covering torque, horsepower and fuel consumption; also specifications. Sent on request.

Attention CITY OFFICIALS

What needed improvement offers more local jobs for your unemployed than storm and sanitary sewers? None, when the pipe are made and the excavating done with local labor.

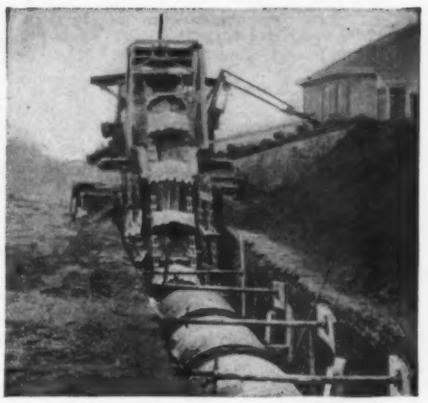
Experienced concrete pipe manufacturers can now come to your city, use Your Labor and Your Materials with the New Portable Dual Packer Head Machine that has made quality pipe, 4 in. to 36 in., for years in their permanent plants.

The Dual Packer Head Machine produces a superior pipe, highly resistant to abrasion and corrosion and provided with New Sealtite joint preventing leaks and excessive infiltration.

Assures greatest economy in production of pipe that, by actual test, have won the acclaim of city and state engineers everywhere.

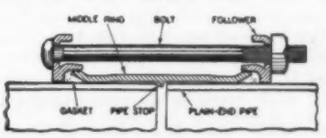
Write for details

CONCRETE PIPE MACHINERY CO.
Dept. PW-1
SIOUX CITY, IOWA



THE DITCHER SURE HAS TO "STEP ON IT" —WHEN THEY'RE DRESSER JOINTS!

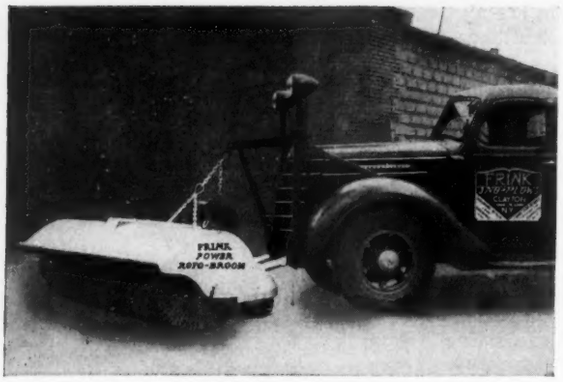
Faster than the ditcher itself can travel—that's how fast a Dresser-coupled line is laid! On a recent 42" line, for instance, trenching often held up a laying crew of only ten men. • With Dressers, no long lengths of trench need be kept open, nor is there any "lag" between operations. Such confinement of all the work to a small area, moreover, permits better supervision.



Cross section, Dresser Steel Coupling, Style 38, showing how it joins *plain-end* pipe in a *flexible*, yet permanently tight connection. Sizes available: ¾" I. D. to largest pipe made.

DRESSER PIPE COUPLINGS

S. R. DRESSER MANUFACTURING COMPANY
BRADFORD, PA.
230 Park Avenue, New York, N. Y.
Peoples Gas Building, Chicago, Ill.
Shell Building, Houston, Texas
1038 Polk Street, San Francisco
In Canada: Dresser Manufacturing Co., Limited, 60 Front Street, West, Toronto, Ontario



Left, Frink's New Power Broom

A truck equipped with pole derrick, jacks, anchor and other tools for line construction. Used by Long Island Lighting Co., Mack Truck (Below)

A Power "RotoBroom" by Frink

A new type power operated broom has been announced by Carl H. Frink, Clayton, N. Y., well-known manufacturer of snow plows. This broom is so designed that it takes the same attachment to the motor truck as does the Frink snow plow, and is therefore readily interchangeable with it. The broom is 8 ft. 6 ins. long, sweeping 7 ft. 6 ins. wide; it is operated by a 4 hp. air-cooled motor through speed reducer, sprocket and chain. A folder will be sent on request to Mr. Frink.

"Moving Stencil" Highway Marker

This keeps the highway worker off the highway—that is, the hazardous job of painting traffic lines is made less hazardous because the man who does it is up on the truck where it's pretty hard even for our best drivers to pick him off. It is a lightweight road marker that can be attached to a motor car or truck and operated by the driver. One man can do 65 to 75 miles of highway per day, the makers state. It will use any kind of paint or hot asphalt and will work equally well on both black-top or concrete. No air compressor is required; a small air-cooled engine operates the pump. Made by Meili-Blumberg Corp., New Holstein, Wisc.

Meili-Blumberg Marker

HOMELITE PORTABLE PUMPS AND GENERATORS

Two short cuts to Lower Construction Costs

THE LIGHT WEIGHT PUMP THAT DOES A BIG JOB

You have two strikes on every pumping job if you use a Homelite 3" Centrifugal Pump. Strike one—you get the pump on the job quicker. It's easily portable. One man can carry it. For it weighs only 91 pounds—complete with built-in gasoline engine.

And strike two—it's a hound for work on the job. A Homelite Portable Pump handles 15,000 gallons of water per hour or keeps seepage down to the strainer level. It is self-priming. Has a 28 ft. suction lift (Guaranteed). Pumps sludge, sandy or muddy water. And it operates automatically without trouble. ***Write for illustrated bulletin.***

HEAD HELPER ON THE NIGHT SHIFT

Homelite Portable Generator speeds night work. Supplies full, brilliant floodlighting that workers need. Complete unit weighs only 89 pounds yet generates 1250 watts—enough for several floodlamps. Excellent for emergencies. Use also—in the day—to operate small electric tools. Write for bulletin.

HOMELITE CORPORATION, Port Chester, N. Y.

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Readers' Service Department

These booklets are FREE to readers of PUBLIC WORKS.

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Feeders, Chlorine and Chemical

387. For chlorinating small water supplies, swimming pools and other installations. Flow of water controls dosage of chlorine (or other chemicals) providing required dosages, which are immediately adjustable. Driving is started and stopped automatically. Send for newest literature. %Proportioneers%, 9 Codding St., Providence, R. I.

Filter Plant Controllers

388. "The Modern Filter Plant" and the uses of Simplex Controllers for operation are described in a handy, 16-page booklet. Charts, data, curves and tables. Simplex Valve and Meter Co., 68th and Upland Sts., Philadelphia, Pa.

Flow Meters

389. The primary devices for flow measurement—the orifice, the pilot tube, the venturi meter and others—and the application to them of the Simplex meter are described in a useful 24-page booklet (42A). Simplex Valve and Meter Co., 68th and Upland Sts., Philadelphia, Pa.

Gate Valves and Hydrants

390. An 84-page catalog gives full design data, information about and illustrations of the complete line of Darling Gate Valves and Hydrants. Write for one to Darling Valve and Mfg. Co., Williamsport, Pa.

391. Two new bulletins on M-H fire hydrants and fully bronze mounted gate valves are now ready. Contain full specifications and instructions for ordering, installing, repairing, lengthening and using. Write M. & H. Valve & Fitting Co., Anniston, Ala.

392. 28 page catalog contains illustrations and complete specifications of M-H standard and extra heavy iron body gate valves, horizontal swing check valves, flanged fittings and flanges, etc. Sent promptly on request by M. & H. Valve & Fittings Co., Anniston, Ala.

Manhole Covers and Inlets

403. Nuisance from loose, noisy manhole covers is eliminated by the use of Westeel rubber cushioned manhole covers and gratings. Six special advantages are explained in a new illustrated bulletin just issued by the West Steel Casting Co., 805 East 70th St., Cleveland, Ohio.

404. Street, sewer and water castings made of wear-resisting chilled iron in various styles, sizes and weights. Manhole covers, water meter covers, adjustable curb inlets, gutter, crossing plates, valve and lamphole covers, ventilators, etc. Described in catalog issued by South Bend Foundry Co., South Bend, Ind.

Pipe, Cast Iron

406. Data on cast iron pipe for water works systems, in sizes from 1¼ to 84 inches, including information on useful life, flow data, dimensions, etc., Thos. F. Wolfe, Cast Iron Pipe Research Ass'n, 1013 Peoples Gas Bldg., Chicago, Ill.

Pipe, 2-inch Cast Iron

407. The new McWane 2" cast iron pipe in 18-foot lengths has innumerable uses in water and sewage work. Send for the new McWane bulletin describing this pipe, the various joints used, and other details about it. McWane Cast Iron Pipe Co., Birmingham, Ala.

Pipe, Large Cast Iron

408. Handy cast iron pipe and fittings catalog contains A.W.W.A. and A.G.I. standard specifications for a wide variety of cast iron pipe specialties, both bell and spigot and flanged; also dimensions Lynchburg Foundry Co., Lynchburg, Va.

409. Information on concrete pipe for sanitary or storm sewers which can be made anywhere by manufacturer using local labor and materials. Write Concrete Pipe Machinery Co., Sioux City, Iowa.

Pipe Forms

411. Making concrete pipe on the job to give employment at home is the subject of a new booklet just issued by Quinn Wire and Iron Works, 1621 Twelfth St., Boone, Ia., manufacturers of "Heavy Duty" Pipe Forms. Sent promptly on request.

Pipe Joints

412. New folder describes in detail a new type of pipe joint—the Dresser Compression Coupling Style 65, which is compact and self contained, makes a permanently tight joint under all conditions and is installed on plain end pipe in a few seconds with only one tool, a wrench. Get your copy today. S. R. Dresser Mfg. Co., Bradford, Pa.

Taste and Odor Control

417. How, when, and where activated carbon can and should be used to remove all kinds of tastes and odors from water supplies is told in a new booklet just issued by Industrial Chemical Sales Div., 230 Park Ave., New York, N. Y. 32 pages, table, illustrations and usable data.

418. Information on activated carbon for taste and odor control including data on operating experiences. Write L. A. Salamon & Bro., 216 Pearl St., New York, N. Y.

Pumps and Well Water Systems

420. Installation views and sectional scenes on Layne Vertical Centrifugal and Vertical Turbine Pumps, fully illustrated and including useful engineering data section. Layne Shutter Screens for Gravel Wall Wells. Write for these three descriptive booklets. Layne & Bowler, Inc., Dept. W, General Office Memphis, Tenn.

Pumping Engines

424. "When Power Is Down," gives recommendations of models for standby services for all power requirements. Sterling Engine Company, Buffalo, N. Y.

Run-off and Stream-Flow

425. Excellent booklet describes and illustrates the latest types of instruments for measuring run-off, both from small areas for storm sewer design, and from large areas for determining water shed yield. Sent promptly by Julien P. Friez & Sons, Baltimore, Md.

Screens, Sewage

428. Be assured of uninterrupted, constant automatic removal of screenings. Folder 1587 tells how. Gives some of the outstanding advantages of "Straightline Bar Screens" (Vertical and Inclined types). Link-Belt Co., 307 N. Michigan Avenue, Chicago, Ill.

Setting and Testing Equipment for Water Meters

430. All about setting and testing equipment for Water Meters—a beautifully printed and illustrated 40 page booklet giving full details concerning Ford setting and testing apparatus for all climates. Ford Meter Box Co., Wabash, Ind.

Rainfall Measurement

432. The measurement of precipitation, exposure of gauges, description of apparatus for measuring rainfall, both rates and amounts. Bulletin RG and Instruction Booklet. Julien P. Friez & Sons, Baltimore, Md.

Screens

435. Water Screen Book No. 1252, describes traveling water intake screens and gives complete technical information about them. Link-Belt Co., 307 No. Michigan Ave., Chicago, Ill.

Sewage Filters, Magnetite

436. Well illustrated booklet describes the magnetite filter, and tells how it is used in the treatment of Sewage. Copy on request from Filtration Equipment Corp., 10 East 40th St., New York, N. Y.

Small Septic Tanks

438. Septic Disposal Systems, Waterless Toilets, Multiple Toilets for Camps and Resorts, and other products for providing safer sewage disposal for unsewered areas are described and illustrated in data sheets issued by San-Equip, Inc., 700 Brighton Ave., Syracuse, N. Y.

Sludge Incineration

440. Disposal of Municipal Refuse: Planning a disposal system; specifications. The production of refuse, weights, volume, characteristics. Fuel requirements for incineration. Suggestions for plant inspection, 45 pp., ill. Also detailed outline of factors involved in preparation of plans and specifications. Morse-Boulger Destructor Co., 202P East 44th St., N. Y.

Swimming Pool Equipment

444. A new booklet "Essential Factors in the Design and Layout of Swimming Pool Systems," with data on filtration equipment, fittings, solution feeders, accessories, etc., is available from Everson Manufacturing Co., 213 West Huron St., Chicago, Ill.

445. Data and complete information on swimming pool filters and recirculation plants; also on water filters and filtration equipment. For data, prices, plans, etc., write Roberts Filter Mfg. Co., 640 Columbia Ave., Darby, Pa.

446. 40-page Manual on swimming pools. Includes swimming pool layouts, specifications, etc., and details concerning Permutit Swimming Pool Equipment. Write The Permutit Co., Dept. G-4, 330 West 42 St., New York, N. Y.

Treatment

450. Standard Sewage Siphons for small disposal plants and PFT Rotary Distributors are new catalogs recently issued by Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill. The latter catalog contains typical plans and many illustrations of actual installations.

453. New booklet on Link-Belt Circuline Collectors for Settling Tanks contains excellent pictures and drawings of installations, sanitary engineering data and design details. Link-Belt Company, 307 North Michigan Ave., Chicago, Ill.

454. Full information regarding their newest equipment for sewage treatment and water purification will be sent on request by The Dorr Co., 570 Lexington Ave., New York, N. Y.

Water & Sewage Treatment Chemicals

500. Aluminum sulphate and ferric chloride for sewage coagulation, and these chemicals and ammonia, copper sulphate and others for water treatment. Information on uses and methods sent on request to General Chemical Co., 40 Rector St., New York, N. Y.

501. "Ferrisul for water and sewage treatment." What it is; what it will do for you and how to use it—a handy booklet issued by Merrimac Chemical Co., Everett Station, Boston, Mass.

Valve Box Tops

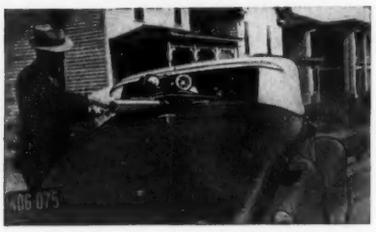
475. "Cut the Cost, but Not the Pavement," is the theme of a new bulletin on Rite-Hite Valve Box Tops. Gives directions for forming new tops on valve boxes, quickly and inexpensively without digging up the old box. Just issued by Trohn's Supplies, Inc., 205 Hoyt Ave., Mamaroneck, N. Y.

Water Works Operating Practices

490. "What Is New In Coagulation" is an excellent, new review with bibliography and outlines of latest work done in the field. Written by Burton W. Graham and sent free on request to Activated Alum Corp., Curtis Bay, Baltimore, Md.

% CHEMICAL FEEDERS %

Are YOU ready for this spring's floods?

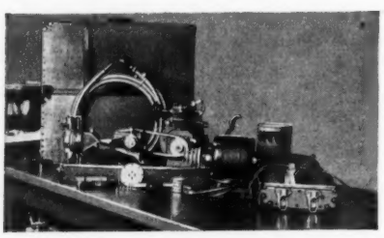


Board of Health Emergency Unit—with 1/5 H.P. gasoline engine and interchangeable 1/6 H.P. electric motor.

Orders already received from the California flood areas have found %Proportioneers% ready in 1938 — as they were in the floods of '37 and '36— to serve water works and public health authorities with Chlor-O-Feeder equipment in the quickest possible way.

Chlor-O-Feeders are ideal for flood service in that they are: 1. Shipped from stock; 2. Small—easy to carry; 3. Easy to install; 4. Immediately effective in making water safe; and 5. Low priced.

Remember that quick action and dependable hypo-chlorinators are most important in preventing disease epidemic following a flood. Many communities play safe by keeping a few portable Chlor-O-Feeders on hand for immediate use in any kind of emergency!



Board of Health Portable Emergency Unit easily fits into car—ready for use anywhere.

Don't Miss the
TWIN GHOSTS of PURITY
BOOTH 8—New Orleans!

% PROPORTIONEERS % Inc.

Associated with Builders Iron Foundry
96 Codding Street
PROVIDENCE, R. I.

For the Engineer's Library

Brief reviews of the latest books, booklets and catalogs for the public works engineer.

Accident Prevention in Construction:

The 1938 edition of the 372-page "Manual of Accident Prevention in Construction" has been published by the Associated General Contractors, Munsey Bldg., Washington, D. C. Pocket size: cloth bound. Of particular interest to highway builders is the section covering temporary bridges, guards, lights and signs, detours, removal of trees and branches, and the sections devoted to highway construction equipment and construction operations. Also covered are trenching, excavation, demolition, masonry, scaffolding, fire prevention, electrical work, and many other items. This has been adopted as recommended practice by the American Standards Ass'n. The price is $2.

Fumigation Manual:

The Insecticide Department of the American Cyanimid & Chemical Corp., New York, has prepared an excellent 38-page manual on fumigation. It is written around the use of their material but is generally very valuable. Includes: preparing the building; dosages and exposures, fumigation operation in detail; common household insects, as roaches, bedbugs, silverfish, fleas, termites, etc.; commodity insects, as the various moths (flour, meal, tobacco) and weevils and beetles. Also general information, rules and precautions. Sent on request, we believe. Best text we know of on the subject.

Rat Control:

Rats are always found in large numbers in and around dumps, as city dumps where they find both food (from garbage) and shelter. We have never felt that rat eradication is the complete answer—disposal of the refuse by incineration is the only real solution—but the American Cyanimid & Chemical Corp., New York, N. Y., has a good folder on the use of "Cyanogas" for cleaning out the rat population. Also a report and description of methods used in Tacoma, Wash., whereby rats were eliminated as an important nuisance and economic factor. Costs are given. We can recommend this data. Sent on request.

Horizontal Cylinder Capacity:

E. L. Peffer of the National Bureau of Standards has prepared tables so that the contents of completely and partially filled horizontal cylindrical tanks may readily be obtained corresponding to the inside measurements. The table shows the volume, in gallons, of a section 1 inch in length, for tanks of various diameters filled to various depths. The total volume of liquid in a tank filled to a given depth can be obtained by multiplying the tabulated volume per inch in length, for a given diameter of tank and depth of liquid, by the length of the tank, in inches. This publication, Circular C416, is obtainable from the Superintendent of Documents, Government Printing Office, at 5 cents a copy.

For Water Works Operators:

This excellent test is composed of the papers presented at the Texas Water Works Short School and edited and arranged by Prof. E. W. Steel. There are 19 chapters and five appendices. The chapters cover Water and Its Impurities, by E. W. Steel; Surface Supplies, John B. Hawley; Sanitation of Surface Supplies, W. E. Roberts; Ground Water Supplies, C. R. Harvill; Pumping, L. A. Quigley; Measurement of Water, E. W. Steel; Storage Reservoirs, J. B. Wonder; Distribution, A. R. Davis; Treatment, L. C. Billings; The Plant, W. S. Mabie; Disinfection, Fred Puckhaber; Algae, Chester Cohen; Softening, T. C. Green; Corrosion, S. C. Clark; Industrial Water, D. W. Robinson; Tests, L. O. Bernhagen; Bacteriology, I. M. Lewis; State Requirements, J. N. Hinyard; and Licensing, W. T. Gooch. Appendices inclue specifications for water works materials, laboratory equipment, conversion factors and a list of useful publications, which we note with regret is very incomplete.

No price is stated on this text, though we have the impression that it sells for $1. Write Texas State Department of Health, Austin, Tex., for further information. In the words of the movie reviewers—★★★

Air Conditioning With Well Water:

This is an excellent article, full of practical information, on the use of well water for air-conditioning. It gives layouts of installations; shows curves and charts for various temperature rises; has a typical sheet for figuring b.t.u. loads; shows a psychometric chart; and, in fact, gives a good elementary education in this subject. Prepared by the Trane Co. and published by Edward E. Johnson, Inc., St. Paul, Minn. We believe a copy will be sent on request.

Pump Lubrication:

The lubrication of the various types of pumps is treated in the March issue of Lubrication, published by the Texas Co., 135 East 42nd St., N. Y. Excellent sectional views of pumps are shown, their design, construction and motive power discussed, and information regarding type and method of lubrication is given. Copies on request to Texas.